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A SURVEY OF THE EFFECTS OF LOAD-CARRYING AND EQUIPMENT DESIGN UPON TASKS PERFORMED BY THE COMBAT INFANTRYMAN

PREPARED FOR:

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A SURVEY OF THE EFFECTS OF LOAD-CARRYING AND EQUIPMENT DESIGN UPON TASKS PERFORMED BY THE COMBAT INFANTRYMAN

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SUMMARY

This survey was conducted with two purposes in mind:

1. To collect, organize, and summarize information about the effects of equipment design and load-carrying upon the performance of the infantry foot-soldier.

2. To identify gaps in this field of knowledge and suggest fruitful areas for future research.

The scope of the study was limited to design of hand-held equipment, design of man-portable crew-served equipment, and design of loads, load-carrying devices and techniques. Primary interest was in the effects of these factors upon combat performance, but measures of physiological activity have been covered to a limited extent.

Information sources included reports of laboratory research, field test and evaluation reports, training studies, Army staff studies and conference reports, opinions of combat officers and field personnel, reported observations of other cultural groups, and miscellaneous published articles. Over 343 literature sources were examined, and 62 of these were selected for more intensive study and abstractions of data.

Readers interested in general results of work on the effects of equipment design upon the performance of the infantryman are referred to Sections I through IV. Those interested in specific data applicable to the design of equipment will find Appendices A and B most useful. Those primarily concerned with areas needing research effort will find Section V and Appendices C and D of major interest.

The most important <u>general</u> conclusion of the study is that available data relating infantry equipment design to soldier performance is inadequate to provide a solid basis for developing a design guide for man-carried equipment. Available data are summarized in Handbook form in Appendix B, according to type of equipment, but substantial supplementation, based on controlled studies of performance as a function of design, is considered a major requirement.

The major <u>specific</u> conclusions are presented below.

A. Load-Carrying

1. The generally recommended maximum combat load for a rifleman is about 40 pounds, and for a non-rifleman, about 45 pounds. Combat load would include only existence items (basic clothing and equipment) and battle items (weapons and ammunition). The generally recommended maximum marching load is about 55 pounds. Marching load would include comfort items which would normally be dropped by a soldier before entering combat.

2. Actual combat loads being carried have been reported to be as high as 62 pounds for a rifle squad leader, and 77 pounds for an M60 machinegunner.

3. Design of load-carrying devices can affect performance and subjective preferences; design recommendations drawn from a variety of studies have been presented.

4. Size and shape of loads have not been systematically studied; in any event, these factors are related to the types and design of the items being carried, as well as to the terrain conditions.

5. Low back carriage appears to be preferable to high carriage for most purposes and for loads above 46 pounds; thigh carry is undesirable; the Bell "Hip Pack" apparently has several important advantages.

6. Despite the fact that the jerkin has not been accepted for Army use, available data suggest several advantages in the jerkin concept. The T53-8 Experimental Pack also has proven effective.

7. Techniques for load-reduction include use of light-weight materials, special packs for special missions, use of multi-purpose equipment, training for survival with minimum equipment, and revamping of supply and logistics techniques to meet infantry requirements.

8. Reports of African porters carrying loads up to 150 pounds (and in some cases up to 250 pounds) suggests that training or use of novel techniques might facilitate load-carrying.

B. Design of Equipment (other than load-carrying devices)

1. The rifle has been more extensively studied than any other equipment.

2. Studies of marksmanship with the M1 rifle indicate that:

   a. Performance is improved by:

      1) Loop sling (as compared with other slings)

      2) Use of sling during training

   b. Performance is unaffected by:

      1) Rifle weight from 9.8 to 14.25 pounds (when fired from the prone position)

      2) Use of personalized stocks and preferred comb configurations

   c. Upper limit recommended for recoil is 19.3 foot-pounds.

3. The M67 recoilless rifle which weighs 44 pounds (including one round of HEAT ammunition) hinders mobility of the rifle crew.

4. Indigenous personnel of Southeast Asia prefer the M2 carbine, which is shorter and lighter than the M1 rifle.

5. Soldier maneuverablity as a function of rifle size and weight has not been studied (except for the M67 recoilless rifle), nor have the effects of prior load-carrying upon marksmanship.

6. Equipment evaluation of the T201 mortar revealed many design deficiencies, several of which would presumably hinder set-up and maintenance, as well as operation. These deficiencies are noted to focus design attention on an area requiring significant improvement.

7. The relationship between human engineering design features and performance for other types of infantry equipment has not been studied to any appreciable extent.

8. Design requirements of indigenous personnel have not yet been determined, nor have the requirements of U.S. troops for guerrilla warfare in jungle terrains.

C. Performance Measures

1. Physiological measures, although frequently used and relatively precise, have not been systematically correlated with other behavioral measures, and are usually insensitive to subtle design variables. They are useful, however, in determining metabolic cost of load-carrying and other physical activities.

2. Subjective ratings of gross bodily activities related to mobility and maneuverability have been commonly employed in evaluating loads and load-carrying devices. Observer ratings of these activities could be made more reliable if principles of experimental design were followed in field tests.

3. Primary tasks (e.g., weapons firing) have been measured for the most part in evaluating rifle design. However, with highly trained subjects, even these measures are not likely to be sensitive to minor design variations unless the task is made more realistically difficult by combining it with maneuvering activities or load-carrying.

4. Secondary tasks (e.g., set-up, calibration, maintenance) assume major importance in evaluating crew-served equipment, and should be used more extensively. Task-equipment analysis can help identify critical tasks, and time and motion study can aid in obtaining precise measures.

5. Human engineering evaluation of hand-held infantry equipment is severely limited by the lack of basic design data for use as criteria. The systematic collection of performance data on which to base such a guide is a major requirement.

D. Research Problems

Fruitful areas for research are listed below, in approximate order of importance:

1. Development of load-reduction techniques, through

    a. Continued efforts to develop light-weight materials

    b. Exploration of the concept of "special loads for special missions"

c. Exploration of the use of indigenous burden carriers, animals and wheeled vehicles

d. Exploration of new techniques of supply and logistics

2. Research aimed at designing pack-carried items for easier load-carrying as well as for meeting performance requirements.

3. Trade-off studies comparing cost and effectiveness of special-purpose vs. multi-purpose equipment for special combat missions.

4. Collection of basic anthropometric, behavioral and cultural data on indigenous personnel, on which to base design or selection of weapons, tools and other equipment furnished to them by the U.S.

5. Methodological studies to develop better measurement techniques during simulated combat operations.

6. Analyses aimed at determining relationships among several types of activity measure (e.g., physiological measures, observer ratings, performance, etc.), and between these measures and other more fundamental criteria of infantry performance effectiveness.

7. Systematic study of load-carrying techniques employed in other cultures, to determine the extent to which load-carrying might be facilitated through training or the use of novel techniques.

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SECTION I

INTRODUCTION

A. Purpose of the Study

This study developed out of a conviction that information about the effects of equipment design and load-carrying devices upon the performance of the combat infantryman was scattered and incomplete. It was felt that a survey and summary of the work that has been done in this field would serve two useful purposes:

1. It would provide an organized summary of information from a variety of sources which would be of interest and value to designers, evaluators, and users of hand-held infantry equipment.

2. It would permit an identification of the gaps in this field of knowledge, and thus form a basis for the planning of research aimed at filling the gaps and expanding the data base upon which future design decisions could rest.

These, then are the dual purposes of this study.

B. Scope and Method

The focal point of the investigation is the combat foot soldier and the manner in which his performance is affected by the design of hand-held equipment, the design of man-portable crew served equipment, and load carrying techniques and devices. Although obviously related, factors such as the design of clothing, and the effects of weather and terrain, are not of central interest here. They are covered only insofar as they have been included as variables in the studies which have been examined, or to the extent that certain types of clothing (e.g., the jerkin) may be considered as essentially a load-carrying device. Furthermore, the performance measures of central interest here are those characterizing tasks performed by a soldier during combat; studies utilizing physiological measures such as pulse rate, body temperature and electromyograph readings are covered only to a limited extent in this survey.

Source materials of various types were drawn upon. They vary markedly in their quality when evaluated as peices of experimental research. However, the intent of the survey was to identify information of any type bearing on the central question, to organize it systematically, and to identify promising leads for further research. Therefore, although reports of laboratory experiments have been drawn upon to the extent that they were relevant and available, other types of sources have also been used. In approximately decreasing order of scientific validity, these other sources include:

- Field test and evaluation reports
- Reports of training exercises under simulated combat conditions
- Army staff studies and conference reports
- Opinions of combat officers and field personnel
- Reported observations of other cultural groups
- Miscellaneous published articles

In all, over 343 literature sources were given at least a preliminary screening. These were drawn primarily from the HumRRO Library in Washington, D. C., the Technical Library of the U. S. Army Infantry School at Fort Benning, Georgia, the Library at the U. S. Army Quartermaster Research and Engineering Center, Natick, Massachusetts, the Library at the Institute for Psychological Research, Tufts University, Medford, Massachusetts, and the Research Library at Dunlap and Associates, Inc., Stamford, Connecticut. On the basis of availability, relevancy, and time, 62 items were selected for intensive study. To facilitate data retrieval of relevant design and task information, a format similar to that used in Appendix B of this paper was used. As each study was reviewed, an attempt was made to determine:

1. Major hand-held or man-ported equipment unit or load-carrying device used, e. g., M1 rifle, hand grenade, rucksack, etc.

2. Task or activity the soldier or subject performed while using, wearing or carrying the equipment unit.

3. Weight of the equipment.

4. Mode of carriage (i. e., how it was held or carried, or to what part of the body it was affixed).

5. Conditions under which the study was performed (i. e., laboratory or field, weather, mode of hiking, terrain, real or simulated combat).

6. Measures used to assess the performance (i. e., task, physiological measure, time, or other measures of capability).

7. **Results.**

A complete list of the 62 references used in this study is given in Appendix C. A supplementary reading list of 281 secondary literature sources are given in Appendix D.

In addition to surveying existing literature, field trips were made to the U.S. Army Special Warfare Center, Fort Bragg, North Carolina, the U.S. Army Infantry Board and U.S. Army Infantry School at Fort Benning, Georgia, the U.S. Army Infantry Human Research Unit at Fort Benning, Georgia, the U.S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, and the U.S. Army Quartermaster Research and Engineering Command at Natick, Massachusetts.

A complete list of the individuals with whom meetings and discussions were held and to whom inquiry was directed by correspondence is given in Appendix E.

SECTION II

LOAD-CARRYING

A. Introduction

The single task which perhaps best characterizes the infantry foot-soldier is that of load-carrying. Despite continuing efforts to develop lighter weight materials for equipment, supplies and clothing, the loads carried by foot-soldiers are commonly regarded as excessive, and according to some observers, continually increase.

This section presents the results and recommendations of studies aimed at determining maximum tolerable loads, and compares these with loads actually carried; methods of load-reduction are examined; results of studies of load-carrying devices are presented and a summary of recommended design features is given; results of studies dealing with size, shape and location of loads are presented; load-reduction techniques are discussed; and, finally, observational data drawn from other cultures are described to suggest what might be achieved through training after other techniques have been exploited to their limits.

B. Forces Exertable by the Human

The relationship between strength and load-carrying ability is relatively unknown. However, studies have been made of the forces that can be exerted by various portions of the human body under various conditions.

One study (62) concerned with determining the strength of the lifting action in man, in which subjects exerted a steady, maximum lifting force on a horizontal bar, concluded only that the difference between overhand or underhand force is small, that the distance of the feet from the frontal plane within which the lifting operation is attempted is of primary importance, that the force decreases rapidly with increase of this distance, and that maximum lifting forces decreases with increase of grasp height. In another study (30) concerned with determining the strength required to resist external force directed against the body, it was found that the ankle is the strongest joint of the body, especially when it flexes, and that arm and shoulder strength are very poor when the arm is extended outward, and especially weak in the overhead position.

Other studies have been concerned with determining the magnitude of forces which pilots can apply to aircraft control devices (1, 2), forces exertable by a man on a specific type of control (28), and speed with which cranks may be turned (37). All these studies have attempted to obtain firm figures regarding strength of the human.

This is not to say, however, that specific recommendations regarding strength and weight lifting, have not been made. Davis (59-s) has suggested that the theoretical maximum lift of a human in the erect position is 500 pounds, and indicates that this figure is achieved by weight lifters. A study (89-s) concerned with carrying sacks both on level ground and up a flight of stairs has recommended that the weight of the sacks not exceed 60 kilograms (132 pounds) while on level ground, and 50 kilograms (110 pounds) while carrying the sack up a flight of stairs. Other studies (19-s) have indicated that, for women, the most economical load appears to be about 35% of the body weight. For example, if a woman weighs 100 pounds, she can reasonably be expected to carry a load of 35 pounds. The same study indicates that a load of 45 pounds is optimum for continuous carriage, and that the average woman should be able to handle 50 pounds without strain. In addition, a woman can carry a possible 20% additional load when the burden is compact and easily handled.

Thus, there have been several laboratory studies concerned with human force exertion and weight lifting. However, for the most part, their applicability to load-carrying by foot-soldiers is questionable. Studies concerned more specifically with combat load-carrying are discussed in the following subsection.

C. Load-Carrying by Soldiers

Much has been written about the total load that a soldier should carry as he goes into combat. It is generally agreed that the soldier's load should be lightened. Marshall (152-s) has recommended that 4/5 of the optimum training load or approximately 41 pounds is the optimum figure indicated for the working combat load. Kelly[1] has indicated that the soldier's carrying capacity can never profitably exceed 45 pounds in combat. In a study performed by U.S. Army Field Forces Board No. 3 (51), it is recommended that 40 pounds be adopted as the combat load to be carried by the soldier employed under the most trying conditions (i.e., the rifleman), that 45 pounds be adopted as the combat load to be carried by soldiers other than riflemen whose combat functions normally require movement on foot, that 55 pounds be adopted as the load to be carried by any soldier when march conditions prevail, and that the loads of other soldiers

[1] Personal Communication: H. E. Kelly, Advisor, U.S. Army Infantry Human Research Unit, Fort Benning, Georgia.

en route to and employed in the combat zone be limited to 55 pounds without regard to the type of unit to which assigned or to the method of movement. A study conducted at Fort Benning in 1961 (54) recommended that the load of infantry soldiers be limited to 45 pounds. Hunter and Turl (24) recommended that 40 pounds be recognized as the maximum efficient combat load.

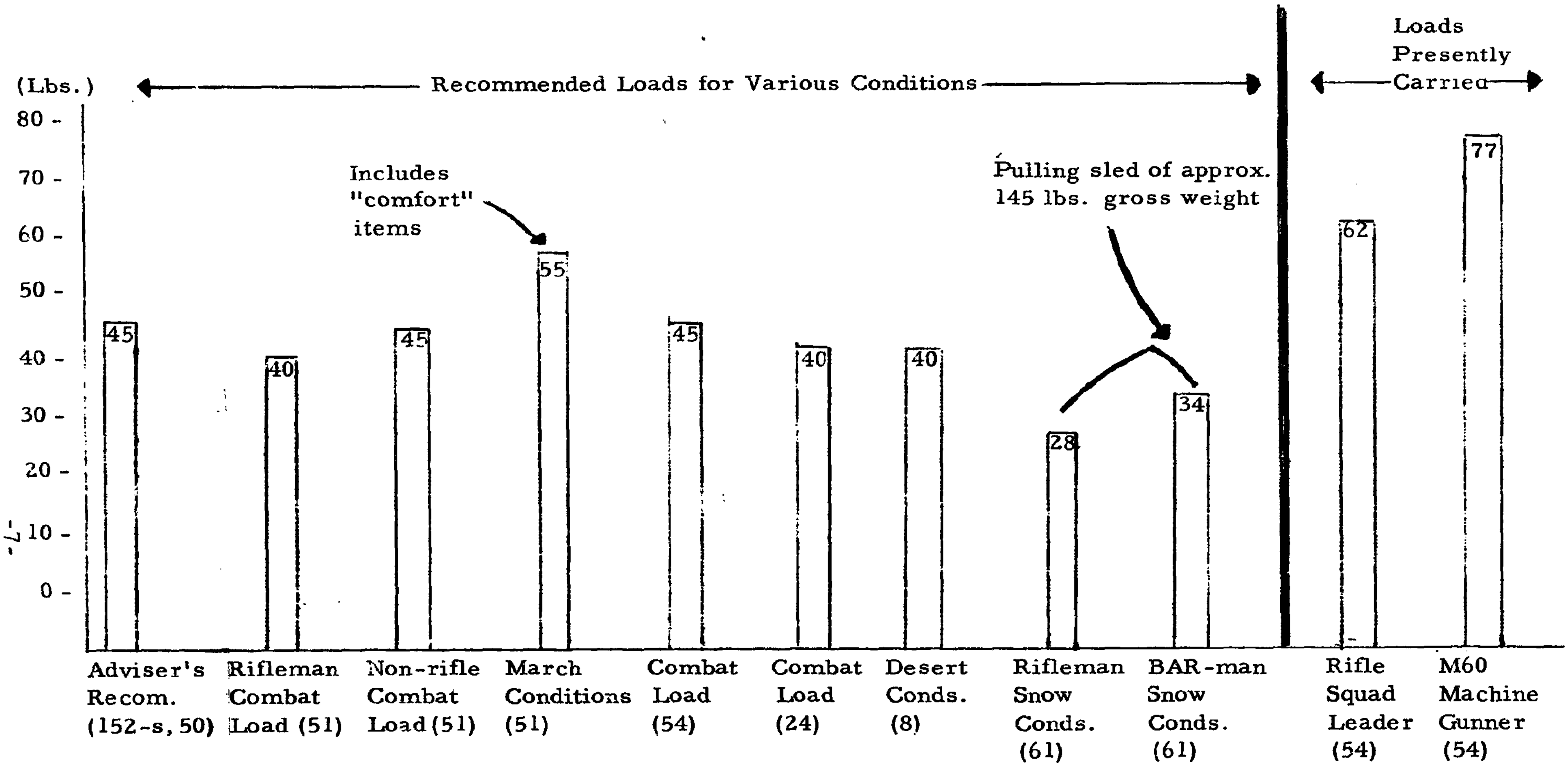
In their review of human load-carrying literature, Teeple and Bereschak (48) indicate that, in general, studies made in an attempt to find an optimum weight have yielded figures ranging from 30 to 40% of body weight. Bailey and McDermott in their review of research on load-carrying (12-s) note that there is a rise in energy expenditure when weight load is increased beyond 40% of body weight. If one takes 154 pounds (101-s) to be the weight of the 50th percentile of Armed Forces personnel, the infantryman can be expected to carry loads ranging from approximately 46 to 62 pounds.

In their study of pack-carrying in the desert, Daniels and Winsmann (8) indicate that a 40-pound pack carried at a rate of 2.5 mph continuously for 1/2 hour appears to represent the extreme upper load limit to carry in any sandy area on the desert. Vaughan and Daniels (61) in their study of the energy cost of sled pulling by one man suggest that, while hauling sled loads of about 145 pounds gross weight over level snow at sub-zero temperatures, the load carried by the rifleman on his person be reduced to 28.2 pounds, and that carried by the Browning Automatic Rifleman be reduced to 34.0 pounds. These figures are exclusive of the arctic clothing worn by the subjects, which weighed between 25 and 35 pounds.

These recommendations for load-carrying under varying combat and climactic conditions are summarized and contrasted with some loads presently carried by infantry personnel in Figure 1.

As shown on the chart, some infantry personnel are presently carrying combat loads of 62 to 77 pounds. If this is compared with the 40 to 45 pounds generally recommended as maximum for combat loads, it is clear that the exploration of various techniques for achieving load-reduction for the foot-soldier is a critical area for research.

It should be noted that, on the whole, the studies cited above are based either on observational reports or on physiological measures. There is a



Note: Numbers in parentheses refer to reference sources.

Figure 1. Recommended and Actual Combat Loads Carried by Infantry Personnel.

Includes "existence" items (basic clothing and equipment), and "battle" items (weapons and ammunition).

Excludes normal clothing being worn, and "comfort" items.

serious lack of data based on controlled experiments in which the load-carrying situation is varied and standard measures of task performance are obtained. Furthermore, no studies have been found in which measures have been obtained of tasks performed after load-carrying (which is a frequent requirement imposed on the foot-soldier); studies of this type might show significant performance degradation with loads even lighter than those which are specified as "able to be carried."

D. Design Features

The literature review revealed a number of design recommendations applicable to the design of load-carrying devices. That such features do measurably influence task performance is perhaps best seen in the study performed by Hunter and Turl (24). In this study, an attempt was made to assess the differential effects of carrying the British "Battle Order" and "Fighting Order" upon task performance.

The "Battle Order" load-carrying system consists of anteriorly located pouches, carried above the waist on the right and left sides, and a small, dorsally located, back pack supported between the shoulders. In the "Fighting Order," the small back pack is replaced by equipment carriers located dorsally on the right and left sides, and a gas cape roll containing additional equipment.

The "Battle Order" was found to have the following objectionable design features:

1. Small pack presented a high and characteristic prone silhouette.

2. Small pack was not readily accessible and contributed to greater instability because of its height above the normal center of gravity of the body.

3. Small pack was unable to be secured without undue restriction of shoulder girdle and respiration.

4. Small pack prevented normal dissipation of sweat over a large area of the back and was conducive to chafing and discomfort in the back area.

The "Fighting Order," on the other hand, had the following design features which apparently favored optimum performance:

1. Provided a better distribution of weight with elimination of constant strain on muscles.

2. Offered greater freedom for muscular effort, particularly of the shoulder girdle.

3. Did not interfere with breathing or constrict the chest.

4. Reduced mechanical movements about the body's center of gravity, thus increasing stability.

5. Permitted greater mobility.

6. Offered a reduced silhouette.

Among other things, it was found that passing through barbed wire was consistently performed in less time by men in "Fighting Order" and that less time was required to sprint 25, 50 and 100 yards when wearing the "Fighting Order" under similar conditions.

Other studies concerned with load-carrying have also been reviewed and pertinent design conclusions abstracted. To assist the designer of load-carrying devices, these conclusions have been brought together and are listed below. Numbers in parentheses indicate the reference from which each was taken.

1. Load-carrying systems should permit freedom of movement for flexion of the leg at the hip. (17)

2. The weight of the load should be distributed over a wide area. (46)

3. The weight of the load on the back should be at least partially balanced by a load on the front (46).

4. All loads should be as close to the body as possible. (46)

5. All loads and associated components should be as close to the body center of gravity as possible. (46)

6. There should be little pressure or compression applied to the chest or armpits. (46)

7. Load-carrying in cargo pockets on legs or on thighs should be avoided. (46)

8. Load-carrying devices should be designed to minimize sway and "shucking" up and down. (46)

9. Straps, attachments, hooks, buttons, buckles and methods of fastening should be minimized and simplified for rapid use and quick disconnect. (46)

10. Load-carrying devices should be designed so that minimum silhouette is presented by the soldier in the prone position. (46)

11. Load-carrying devices should be designed so that local strain is eliminated by transmitting weight to the ground through bone. (27)

12. Load-carrying devices should be designed so that there is minimal interference with regulation of body temperature. (27)

13. Volume taken up by load-carrying system should be minimal so that many can be carried by vehicle. Packs should therefore be designed so that they are cubical or cylindrical in shape, preferably soft walled, and must not have metal frames protruding from them. (27)

14. Load-carrying devices should be made of light-weight, waterproof materials. (13)

15. Rattling and bouncing of load components should be minimized. (52)

16. The back should be protected from hard, sharp or irregular loads. (6)

17. Load-carrying devices should permit ease of entry and rapid jettisoning in case of emergency. (6)

18. Strain on the shoulder muscle should be minimized. (24)

19. Load-carrying devices should not interfere with movements of the shoulder girdle. (24)

20. Mechanical movements about the body's center of gravity should be reduced. (24)

21. Ease of access to critical or frequently used load components should be afforded to the soldier with the load on his back. (24)

22. Load-carrying devices should allow for maintenance of normal posture. (147-s)

23. Maintenance of a normal and free gait should be considered when designing load-carrying devices. (147-s)

In addition to the design recommendations specified in the literature, designers of load-carrying devices should also consider:

1. Purpose, conditions and terrains under which load-carrying device is to be used.

2. Carrying and operating equipment without removal from load-carrying devices.

3. Personal comfort of the porter.

4. Contour design of packs.

5. Camouflage of the pack.

6. Arrangement and quantity of load components so that the first needed is most readily available (i.e., bayonet in front, canteen in back).

It is interesting to note that while several studies have been performed demonstrating the effects of load-carrying upon performance (5, 6, 7, 9, 11, 13, 17, 21, 24, 27, 28, 42, 50, 51, 52, 54, 57-61), in relatively few studies have the specific design features affecting performance been identified. More carefully controlled experimentation would be required to reveal many of the effects of individual design features upon task performance.

E. Size of Load-Carrying Devices

A review of the literature indicates that relatively little research consideration has been given to the size of load-carrying devices as it affects task performance of the combat infantryman. In one study (13), the results indicated that the existing design of magazine pouches on the Battle Jerkin was too small. Another study (52) which attempted to determine whether the standard packboard (24" x 15") can be reduced in size without effect on the wearer, indicated that there was no advantage in having the wearer use a reduced size packboard.

It would seem reasonable to assume that results of anthropometrical studies might be applicable to the design of load-carrying devices. However, in the allocation of space and size requirements for a load-carrying device, there are a number of unique problems, not necessarily found in the design of other equipments, which require specialized consideration. The combat infantryman performs physical tasks requiring many different modes of body operation, and utilizing a wide variety of equipments, tools and weapons. It is important that the size of the load-carrying device reflect a proper balance between the requirement for enough storage space, and the requirement not to interfere with body movement and task performance. In addition, the design requirements are, to a large extent, dependent on the design of the individual items to be carried, although the potential advantages of designing these items to fit standard load-carrying devices suggests another fruitful area of research.

F. Shape of Load-Carrying Devices

No systematic study of the effects of shape of load-carrying devices and associated components upon task performance has been made. In one study (27) it was noted that the storage space of the Bergen Rucksack is excessive and that the curved metal frame of the rucksack is of awkward shape. This same study urged that packs be designed so that they are cubical or cylindrical in shape, preferably soft-walled, and not have irregular metal frames protruding from them, in order to keep pack volume minimal, and hence occupy less storage space.

Combat terrain features may dictate preferable pack shapes. For example, discussions with Special Warfare personnel revealed advantages for back packs which are long and narrow rather than wide and flat, despite some of the general design recommendations cited previously. The reason for this preference is that wide packs tend to be caught in jungle underbrush. A suggestion by one of the Special Warfare personnel was that packs should extend back from the shoulders, rather than up and out.

It is interesting to note what Carre (33-s) indicates about the historical genesis of the wooden framed knapsack. He suggests that:

1. The rigid sack was conceived by a young recruit, not by an old soldier with field service who had carried a load in campaign.

2. It was created for a review, that is, to be worn empty. Its adoption was influenced by its fine regular shape and well-aligned sides, rather than by its proven performance.

Subjective factors, rather than systematic investigation, have evidently dictated the shape of the French knapsack, as well as U.S. Army packs. In general, little research has been performed on the effects of pack shape upon soldier performance.

G. Location of Load and Load-Carrying Devices

Many studies have been performed and recommendations made regarding that portion of the body which can best bear loads. Table 1, after Gray and Leary (15) indicates those parts of the body used for load-carrying in Africa.

Table 1. Parts of the Body Used for Burden-Carrying in Africa

1. Hand Carry	11. Back Sling
2. Arm Carry	12. Back Sling Variation: carrying item on back with sling around waist
3. Shoulder Carry	13. Pick-A-Back Carry
4. Back Carry	14. Tumpline
5. Head Balance	15. Shoulder pole, one person
6. Head Pad	16. Shoulder pole, two or more persons
7. Multiple Head Carry	17. Front Sling
8. Single Shoulder Suspension	
9. Hip Carry	
10. Hip Sling	

As the table readily shows, virtually all parts of the human body are used for load-carrying except the legs and chest. Bedale (19-s), employing one test subject, studied the energy cost of carrying a number of loads up to 60 pounds on different portions of the body. In comparative energy cost studies, the rucksack carried low on the back fared poorly, carrying the load on one shoulder was better, but carrying the weight suspended from shoulder yokes was clearly superior. The Yoke method was most favorable from pulse, blood pressure, and subjective criteria. Table 2 shows oxygen consumption of the subject in cc./min. for the various methods of load-carrying.

Vanderbie and his associates (57) believe that there might be a slight advantage in carrying weights up to about 46 pounds high on the back and heavier weights low on the back while using a packboard. In another study

Table 2. Oxygen Consumption in cc. /per min. for Various Methods of Carrying

Weight in Pounds	20	30	40	50	60
	Oxygen Consumption per Minute				
Methods of Carrying					
1. Tray carried in front of body	464	522	613	675	---
2. Tray carried in front, strap around shoulders	473	522	604	656	---
3. Weight carried in equal bundles in each hand	455	492	534	667	---
4. Weight distributed on board on left shoulder	428	547	609	608	778
5. Tray on left hip	574	657	694	725	---
6. Rucksack on back	561	573	608	700	---
7. Weight in two pails, supported by shoulder yoke	400	440	486	516	531
8. Tray on head	527	575	626	692	---

(59), Vanderbie indicates that carrying 15 pounds on the thigh (7-1/2 pounds per thigh) leads to energy expenditure equivalent to carrying 45 pounds on the back. In their review of the literature, Teeple and Bereschak (48) conclude that while optimum position may vary with the weight of the load, studies generally support the low back position, especially for heavier loads.

Daniels et al (7) found that at high speed marching, there was an advantage in using packs which rest low on the back. In a study (11) designed to evaluate Army combat packs by measuring energy costs and speed of movements, it was found that loads carried high on the back interfered with many activities, especially when the soldier "hits the dirt." It would seem, therefore, on the basis of the studies presented above, that for loads up to 46 pounds, or when engaging in activities in which the human remains standing erect, that carriage high on the back is suitable (provided the load is suspended from shoulder yokes). However, for loads over 46 pounds, or when marching at high speed, carriage low on the back is advisable. In addition, carrying loads on the legs is not recommended.

It is interesting to observe that the Bell Aerosystems Company has developed a load-carrying device, the Bell Hip Pack, which they claim "removes the main load from the spine and shoulders of its user and places it on the portion of the body best suited for carrying weights, that is, the pelvic area of the hips." The Bell Hip Pack is a device with a rigid frame made of fiber glass contoured to the shape of the body. It has shoulder straps and a waist belt which are utilized to keep the unit closely coupled to the body. Padding is used on the inside of the Hip Pack to give flexibility and comfort to the wearer. Table 3 indicates performance figures and human engineering principles given by Bell for their Hip Pack.

While much has been written about location of loads and load-carrying devices, emphasis has, for the most part, been placed on studying the total load being carried, to the neglect of the individual components making up the load. The designer of load-carrying devices would be aided by information concerning the requirements for utilizing the various components making up the load (such as, for example, accessibility of survival and first aid kits, manner of use of entrenching tools, etc.).

TABLE 3

Performance Capabilities of Bell "Hip Pack" [1]

Activity	Weight	Operating Time	Lateral Translation
Working under load (spraying insecticides while walking)	75 lbs. 100 lbs.	no limit 1 hr.	no time limit 2.5 - 3.0 mi.
Load-Carrying	300 lbs.	2 min.	100 yds.
Using Hip Pack for jack operations only	500-600 lbs.	5 sec.	None
2 Hip Pack operators for a "double jack" operation	1000 lbs.	5 sec.	None

Human Engineering Principles:

1. Elimination or reduction of load movements with reference to vertical body axis.

2. Equal load pressure distribution on large surface in preferred body areas, especially around the pelvis.

3. Close coupling to human body.

4. Possibility of rigid payload attachment and favorable payload distribution on the device.

5. Free mobility of arms and legs during load carrying.

[1] Bell Aerosystem Company, Hip Pack Carrying Device, Buffalo, N. Y.

NOTE: It is assumed that: a) Activity refers to an activity engaged in while using the Hip Pack, b) Weight refers to weight carried while wearing the Hip Pack, c) Operating Time refers to maximum time activity was performed while carrying a given load, and d) Lateral Translation refers to horizontal distance at 0° grade traversed in time specified while carrying a given load.

H Load-Carrying Devices

This section deals with devices listed under the general category of "Load-Carrying Devices" in Appendix B (Handbook Summary). It should be noted that in most of the studies reviewed for this report, information about design features and, more important, their effects upon performance, was incomplete. However, an attempt has been made to draw whatever information was available, and make careful inferences about the design-performance relationship whenever full information was not forthcoming. The reader is urged to refer to the original source of information, as given by appropriate reference, for further information.

For the convenience of the reader, the discussion order of load-carrying devices will follow that presented in Appendix B.

1. Ammunition Pouches.

Studies performed on ammunition pouches located on the anterior surface of the subject on and above the thigh (7, 11, 17, 52) indicate that pouches located in this manner interfere with movements which require flexion of the legs at the hip joint, and frequently cause pain by pounding on the abdomen and thigh Though performance in a number of activities such as jumping, creeping, falling, and the Burpee test of agility was not adversely affected by the position of the ammunition pouches on two-load carying devices (T53-8 and UK Z. 2 load-carrying systems), and no increase in oxygen consumption or decrease in body movements were discernible, it appears that, for a subjective point of view, ammunition pouches located anteriorly at waist height just above or upon the thigh hinder performance

It is interesting to note that when standard ammunition pouches are compared with experimental ammunition pouches in which ammunition is not permitted to rattle or bounce within the pouch, subjective preference for the experimental pouch is indicated (52).

It is quite possible, therefore, that pouch position is not the only factor affecting performance. It may be that when ammunition is permitted to rattle loose within the pouch, its cumulative detrimental effect, indicated by subjective measures, as it strikes the thigh of the soldier in motion is greater than that of ammunition solidly affixed within an ammunition pouch. This conclusion is given some support by a study (53) which evaluated ammunition bags (or pouches?) used for carrying ammunition for crew-served weapons. While the exact mode of support of the ammunition bags or pouches was not specified, the study suggested that ammunition bags be replaced by devices that could be strapped to the body. Evidently, ammunition pouches should be firmly affixed to the wearer to prevent the pouches or their contents from rattling or bouncing.

2. Bamboo Pole

A survey of the literature indicates that only one study (59) has been performed in which a subject, marching at 3-1/2 miles per hour on a horizontal treadmill under laboratory conditions, carried 15-45 pound loads at the end of a 14-foot bamboo pole. Performance, as measured by physiological measures was poor. Severe stress and pain of the shoulder was noted by subjects using the pole.

It is important to add, however, that burden carrying by means of a pole may require that new techniques of body mechanics and posture be learned. This was pointed out in dicusssions with Special Warfare personnel who indicated that when Viet Namese carry burdens using a pole, they walk with an exaggerated undulation of hips and waist.

It appears that carrying burdens by means of a pole may offer advantages (at least under certain special combat conditions). The pole may be fabricated from locally available materials, quickly jettisoned in times of emergency, and the solder be made immediately ready for combat. Furthermore, it may be easily adapted for load-sharing by more than one man.

It is quite likely that motion-picture studies of indigenous peoples carrying burdens with bamboo poles may suggest techniques of burden-carrying applicable to infantry and guerrilla troops.

3. Chest Carry

No studies appear to have been made concerning the use of the chest for burden-carrying. The only study performed on which a weight was carried upon the chest (59) indicates that the subjects preferred that loads on the chest be balanced by loads on the back. While it is true that unduly heavy loads upon the chest may prevent normal respiration, and bulky loads upon the chest may interfere with such activities as "hitting the dirt" and firing a rifle from a prone position, the use of the chest as an available portion of the body for burden-carrying should not be totally overlooked.

4. Jerkins

The jerkin is a load-carrying device which surrounds the entire torso of the wearer's body. A hole in its center allows the jerkin to be put on over the wearer's head. The front surface of the jerkin contains ammunition pouches, while the rear surface has a detachable pack for carrying personal items, a place for an entrenching tool and a bayonet, and a strap which attaches to a waist belt on which is located a utility pouch and bottle carrier. The front and rear surfaces of the jerkin are connected by a hook and eye fastener at the wearer's crotch. Side hooks on either side of the jerkin at waist level serve to hold the jerkin in place until the waist belt is put on.

Research on the jerkin (13, 38) indicates that it interferes less with the general comfort and performance than do standard back-type packs. In addition, the jerkin appears to be better adapted for long marches than standard back-pack equipment. Further, the jerkin seems to permit a wider range of body movements than do back-packs. A series of subjective and objective tests (13) compared performance of the British Battle Jerkin with the British Z. 2 load-carrying system (which basically consists of a long pack closely adapted to the back with two pouches located anteriorly at the waist) on various combat tasks. Measures included responses to questionnaires, physiological measures, and time required to complete given tasks.

Results indicate that, with the exception of time required to don and doff, the jerkin is generally superior to the Z. 2 equipment as shown by questionnaire response and preference measures. For such activities as running obstacle courses, jumping into and out of ditches, running and climbing, putting on and removing equipment, the jerkin is superior to back-pack-type equipment as determined by physiological and performance time measures.

Design features of the jerkin which appear to have influenced performance include: lightness, simplicity, weight distribution close to the body, stability of load, balance, comfort and water repellance.

A cargo vest comparable to the jerkin was evaluated by the Army Field Forces Board No. 3 (50), and found to have several deficiencies, such as poor ventilation and unbalanced load. It might be possible to alleviate these deficiencies through modifications of design specifications, while retaining the advantages of the basic design concept.

As shown by the results above, the jerkin is a load-carrying device which is demonstrably superior to at least one type of back-pack. Comparisons with other load-carrying devices would be desirable. If consistent results were obtained, other applications of the jerkin design concept might fruitfully be developed.

5. Korean A-Frame

The Korean A-Frame consists of a wooden frame with the general shape of a letter "A." It is carried over the back with the point of the "A" located over the spine at the lower portion of the neck. When it is used for carrying loads, the lower ends of the A-frame are located close to the ground. Two shoulder straps, generally made of straw, extend from near the apex of the "A" to the lower ends of the "A" below the waist. Padded cross-bars connect the two arms of the "A," the lowest cross-bar at a level with the lumbar spine or sacral region. At the level of the lowest cross-bar, projections about a foot long, extend back from the rest of the frame at an angle greater than 90° (6).

It has been reported that 55-gallon drums of diesel fuel weighing 460 pounds, have been carried with the A-frame. A medical officer reported that he saw a Korean carrying 5 bags of rice which weighed 500 pounds. Further reports have indicated that Koreans working in Pusan carried about a cubic foot of wet concrete in home-made metal boxes supported on an A-frame.[1]

While the A-frame may be impractical for use by combat troops who have to run, jump, or fall flat, a number of the design features of the frame may have value in future pack design.

The A-frame design appears to have the following advantages:

. Protects the back from hard or irregular loads because of its rigid structure.

. Minimizes load motion.

. Transmits most of the load weight through bony structures of the pelvis, hips and lower back directly to the ground.

. Applies less pressure to top of shoulder than does standard pack board.

. Brings the center of gravity of the load directly over body center of gravity by forward leaning.

. Permits rapid jettisoning of pack because of the wide separation between origin and insertion of carrying straps.

. Minimizes distance that the load must be lifted at the start.

For the most part, information about load-carrying performance capabilities while using the A-frame is anecdotal in nature. The one study performed (6) using evaluation of photographic studies and direct observation procedures as measures of performance did not specify weight of loads actually carried, and offered only approximation as to the actual dimensions of the A-frame. In addition, there is no information regarding the effects of load-carrying by means of an A-frame upon performance.

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[1] Field Observers Reports, No. 8, July 1954 - December 1954 (Personal Communication, Dr. Jack Pl[illegible]alp).

6. Packboard

The literature review reveals that while a number of studies have been concerned with loads carried on packboards (7, 8, 39, 57, 59), and other studies have considered effects of location and size of packboard on the wearer (16,52) and strap pressure obtained while load-carrying with the packboard (26), no studies appear to have considered how a combat infantryman will perform after carrying a load on a packboard. Nor have the effects of packboard shape upon the wearer been studied. It may be that the hard flat surface of the packboard implies that it can easily sustain heavy loads, with little thought given to the fact that the packboard frame does not bear the ultimate load, but that the foot soldier does. This is perhaps best borne out in a study (39) in which electronic equipment was transported over varying terrains. It was found that several loads were too heavy and required division into several smaller units, that all the weight of an electronic unit was placed on one side of the packboard, and that equipment jutted out from the packboard frame, catching in the brush as the bearer travelled forward. A contoured packboard frame shaped to the back of its wearer might aid load-carrying.

Two studies (12, 26) indicate that straps associated with packboards may be causing excessive pressure upon the wearer's shoulder. This may be due to packboard overloading or to strap design. Of interest is the fact that in one of the two studies concerned with strap pressure (12), strap widths at points of pressure measurements were as follows:

	Strap Width Position on Shoulder	
	Top	Front
Packboard	2 inches	2 inches
Standard Pack	2 inches	2 inches
Rucksack	2-1/4 inches	2-1/4 inches
UK Z. 2	2 inches	2 (modified) inches
T 53-8	3 inches	3 inches

It is possible that packboard strap width is an important factor in causing excessive pressure on the wearer's shoulder. Further, difficulties have been noted in carrying either a rifle or a carbine while wearing a packboard (39, 52). This may be caused by the restrictive influence of the packboard straps upon the arms of the infantryman.

7. Packs, Miscellaneous

Load-carrying devices which were not fully discussed in the literature and whose operational status was not clearly defined are discussed under this heading.

In several studies (11, 17) certain activities could be performed as rapidly with a pack as without one. However, other studies (7, 50, 52) indicate that pack movement is frequently out of phase with the motion of the body, that loads fall away from the body during certain activities and that stabilizing agents are required to prevent shifting of load downward during carrying.

Other design problems reported (50, 52) include difficulties in fastening buckles and straps of load-carrying devices. Speed in putting on and removing packs is a critical requirement, deserving careful design attention.

8. Rucksacks

Although the rucksack may be useful under arctic or mountain conditions (9), several disadvantages have been reported. It has been noted (38), for example, that rucksacks tend to chafe the skin, upset body balance, prevent effective rifle firing from a prone position, and wobble during marching, thus causing discomfort and waste of body energy. In addition, its curved metal frame has been found to be inconvenient when storing groups of empty rucksacks or placing loaded rucksacks on vehicles. Further, rucksack storage space is excessive (27).

9. Sleds

Two studies (60, 61) have considered the sled as a load-carrying device, and in both of these, measures were obtained of the physiological factors involved in sled haulage. Consideration has been given to such factors as pulse rate, energy expenditure, etc., as related to snow conditions. No direct comparisons have been made, however, between load-carrying by sled and by other techniques. Further, haulage by sled need not necessarily be restricted to transporting materials over snow. Specially designed sled runners may permit the use of sleds to haul equipment over desert terrain or through mud.

10. Slings, Bandoleers

In reviewing the literature, it appears that no systematic study has been performed on the effects of slings, straps, bandoleers, or other devices which both constrict and support. Studies have been performed on the support of a light-weight radar by a neck strap (9), straps used to carry ammunition (53, 54), straps used to support load-carrying devices (6, 12, 26) and the effects of slings on rifle marksmanship and health (3, 18, 44).

Studies performed on the effects of slings on rifle marksmanship and health (3, 18, 44) indicate that slings may have a beneficial effect on rifle marksmanship (18, 44), but that they may also cause palsy of the hand (3). However, it is not known what specific sling design features are responsible for these effects. It appears that the sling aids the soldier in steadying his rifle during firing, but when worn around the upper forearm, acts like a tourniquet to restrict circulation. A study to determine which design features of slings (size, shape, weave, weight, location on body, etc.) influence performance may provide this information.

11. Swiss Combat Clothing Ensemble

The Swiss Combat Clothing Ensemble and integrated load-carrying equipment consists of a jacket with attached hood and face camouflage, trousers with attached suspenders, and a rucksack. All required equipment is carried within pockets of the ensemble and the attached rucksack. The empty weight of the ensemble is 20 pounds, 3 ounces.

The ensemble failed to meet the criteria used by the U.S. Army in considering the design of load-carrying equipment. It is discussed here, however, because of:

a) The need of Special Warfare personnel to carry all necessary equipment in pockets of their personal clothing.

b) The increased mobility requirement of combat infantry personnel, resulting in minimum time available for putting on and taking off load-carrying devices and associated components.

A review of the negative design features found in the Swiss Combat Clothing ensemble may enable designers to make necessary modifications and thus furnish a potentially useful load-carrying device to infantry personnel:

a) Jacket doesn't balance well on shoulders under load.

b) Wearer is subject to physical stresses which accompany low pack.

c) Load carried in jacket is relatively unstable while soldier is in motion.

d) Rucksack tends to sway and swing while in motion resulting in load instability.

e) Cargo pockets in trousers are regarded as a hindrance.

f) Weight cannot be distributed on the back between shoulders and hips because of fixed buckles used to suspend rucksack from "D" rings on the shoulders.

g) Ensemble hinders normal respiration.

h) Detaching rucksack from jacket requires too much manipulation.

i) Jacket pockets on chest and abdomen, when filled, do not allow for a low silhouette when lying prone.

j) Clothing must remain on soldier regardless of weather or activity.

k) Camouflage patterns on ensemble were not realistic.

12. <u>Thigh Carry</u>

Studies performed on the effects of load-carrying on the thigh (46, 59) indicate that cargo pockets used for carrying loads are a hindrance. and that load-carrying of 15 pounds on the thighs leads to energy expenditure equivalent to carrying 45 pounds on the back.

Evidently, bulky loads on the thigh interfere with activities that require the combat soldier to lie prone on the ground such as "hitting the dirt" or firing a rifle from a prone position. Although it might be possible to design equipment to fit the contours of the human thigh (such as flat silhouette water containers), thigh carry appears to offer little promise.

13. <u>United Kingdom Z. 2 Pack</u>

The UK Z. 2 load-carrying system is believed to be no longer operational. However, it is discussed here because a review of studies concerned with the UK Z. 2 pack (7, 11, 12, 13, 17, 38) reveals design features which appear to affect performance.

The UK Z. 2 load-carrying system consists of a long pack closely adapted to the shape of the back and connected by means of straps to two ammunition pouches located anteriorly on the waist. A waist belt serves to further affix packs and pouches to the body of the wearer. One study (17) notes that grenade throwing is not as accurate while wearing the UK Z. 2 packs as when wearing other packs. This may mean that the straps and belts of the UK Z. 2 pack are too confining and thus inhibit freedom of arm movement and swing. This latter point is further borne out by the observation of another study (38) that UK Z. 2 equipment is quite stable in terms of clinging to the body. One finds, however, that straps of the UK Z. 2 pack apply lowest pressure on top of the shoulders as compared to other load-carrying systems (12). This may mean that the constricting action of the straps and waist belt of the Z. 2 system operates primarily on the chest of the wearer. However, this constricting effect, if it exists, does not seem to impair the performance involved in doffing and donning the Z. 2 pack or in marching at low speed (2-1/2 to 3-1/2 mph) (13), or to cause any physiological strain as measured objectively or subjectively (38). Performance is impaired, however, with the UK Z. 2 pack in short activities involving running, jumping, crawling and rolling, and it bounces about more than the Battle Jerkin (13). This observation is not inconsistent with the observations that the UK Z. 2 system is stable in terms of clinging to the body and may constrict only at the chest, since it is contrasted with a load-carrying device, the Battle Jerkin, which offers greater attachment surface to the body and hence would be more firmly carried upon the body than the UK Z. 2 system.

14. U. S. Experimental Pack T53-8

The T53-8 load-carrying system with modifications is now operational as the M 56 load-carrying system. Several significant improvements have been made in the standard individual load-carrying equipment as follows (280-s):

a) Standard pistol belt, supported by modified and improved suspenders, to be worn around the waist in lieu of the cartridge belt now worn.

b) Two universal ammunition pouches, each capable of containing a sufficient supply of rifle ammunition, to be attached to the belt and so placed as to provide a desirable counterbalance to the back load pack and sleeping roll.

c) Entrenching tool carrier to be carried on the pistol belt.

d) Position of the combat pack on the belt permits much of its weight to be borne by the pelvic bone. When the sleeping roll is dropped, the combat pack attached to the suspenders can be carried at the waist or carried by hand as a furlough bag.

In reviewing the literature which describes the effects of a T53-8 load-carrying system upon performance, it was found that grenade throwing was as accurate with the T53-8 as without any load-carrying system; that "hitting the dirt" was performed as rapidly while carrying a T53-8 pack as without a pack; and that balance was maintained equally well with the T53-8 as without a pack (17). The T53-8 load-carrying system has evidently been designed to minimize negative effects of load-carrying systems upon performance.

It is of interest to note that these tests of the T53-8 load-carrying system were performed under careful laboratory or field conditions (7, 11, 12, 17).

15. Vests

Research performed on armor vests (8, 50, 58) indicates that vests play a part in inducing physiological stress, due primarily to the increased heat load. This may be due to their weight or to their constricting influence when worn around the body, or to these two factors acting in combination.

16. Waist Carry

Equipment units such as ammunition pouches, canteens, pistols, hand-grenades, entrenching tools, and other combat infantry equipments are waist carried. No studies, however, have focused their major attention on the effects of waist carry upon task performance. The studies which have been performed (57, 59) have considered performance from a physiological viewpoint and have been somewhat inconclusive.

17. Wheeled Carts

Only one study (39) appears to have been performed on the use of a hand-pulled two-wheeled cart for transporting electronic equipment over varying terrains under simulated combat conditions. Results indicate that use of such a cart increases transport time and leaves men in a fatigued condition.

While the results appear to dictate against use of wheeled vehicles, it should be noted that the cart used in the study had two relatively small parallel wheels, making it unsuitable for use in underbrush or over rough terrain. A differently designed cart might facilitate performance.

I. Load Reduction

Promising techniques for reducing the load carried by the infantry foot-soldier include: development of light-weight materials for equipment and clothing, adoption of the principle of "specialized loads for specialized missions," training of soldiers to fight and survive with less equipment, adaptation of certain equipment for multiple usage, and possible revamping of logistics and supply techniques to permit greater use of vehicles for load-carrying.

Modern technology makes it possible to utilize plastics and light-weight, high-strength metal alloys in the manufacture of hand-held or man-ported weapons and ammunition. Clothing and personal items of equipment such as packs, boots, straps, and belts are presently being made of sturdy, light-weight fabrics. Development of weapons and equipment such as the 66mm, M72 light anti-tank weapon, which has a one-shot capability and can be thrown away after use, can help reduce the soldier's load.

In viewing the load-reduction problem, it may be useful to determine what weapons, equipments, and tools are actually required under various conditions of combat. One way of obtaining this type of data is to conduct user and preference studies in order to find out what equipment is used, retained or discarded. Combat veterans may furnish useful information about equipment usage under conditions of combat, as may trained observers. Once this information is available, it may be possible to reduce loads carried by reducing unneeded equipment.

Studies of existing survival and guerrilla training programs may also afford leads for achieving load reduction. Once the combat soldier has been taught how to forage for his personal needs, use field-fabricated weapons, and survive with a minimum of essential equipments, it may be possible to send the soldier into combat with a decreased load.

Marshall (152-s) notes that when the 153rd Infantry Regiment landed at Kiska in the Aleutians during World War II, each member of the regiment carried the following items:

Underwear
Shirt (w/o tie)
Jersey lined trousers
Alaskan field jacket
Helmet, steel
Helmet, liner
Raincoat
Poncho
Extra shoes
Rifle belt
6 grenades
Intrenching tool

240 rounds ammo
Rifle
Packboard
Sleeping bag
2 shelter halves, pole and pins
12 cans C rations
Heat tablets
Cook stove
2 cans Sterno
Long knife
Compass

Book of Battle Songs
Bayonet
Flashlight
Maps
Pocketknife
Change of clothing
Wire cutters
Waterproof matchbox
Identification panel
Rucksack
4 chocolate bars
3 signal panels

As compared with this, the list below itemizes the load more recently carried by a member of a 10-man rifle squad in the Arctic (61):

1 Rucksack
2 Assault packets
2 pairs insoles
1 bag, sleeping, Arctic, w/cover
1 pad, inflatable, sleeping

1 C ration
4 pairs socks
1 toilet articles
1 Canteen (filled)
1 Rifle w/96 rounds
or
1 BAR w/2 loaded mags.

Survival training may have taught these men to live off the land and carry only minimum loads.

Another technique for load-reduction is in the development of multiple-use weapons. For example, the 40 mm, M 79 Grenade Launcher can be used as a hand-held mortar (54). The need for a heavy-weight mortar may thus be obviated, resulting in a decreased infantry load.

Other methods of load-reduction which might be considered include the utilization of indigenous peoples for burden-carrying, the use of specially equipped and trained personnel for carrying ammunition and equipment, and the use of hand push-pull vehicles such as wheeled carts or sleds.

Finally, it might be profitable to analyze the inter-relations between infantry soldier requirements and supply and logistics techniques, to determine whether the latter could be modified in order to satisfy the former to a greater extent than is now possible.

J. Stress and Health

The question of health, more specifically that of stress, and burden-carrying is an interesting one and may have some important implications for the combat soldier. Ginzberg and his associates in their study of the ineffective soldier (88-s) observe that the constant threat of danger, added to the physical stresses of Army life, can result in severe performance degradation.

Although stress has never been adequately defined, one commonly used measure of stress has been eosinophil count. When eosinophil count is low, it is considered an indication of increased corticoid activity and presence of a stress condition. Redfearn (36) in his study of the eosinopenia of physical exercise found that eosinophil count in a group of subjects was depressed after marching 25 kilometers about 6 kilometers per hour while carrying 15-30 kilogram loads.

Marshall (152-s) suggested that the repeated impact of sudden fear in combat can burn up muscle glycogen and result in exhaustion similar to that caused by physical activity.

Lothian (148-s) has suggested that a relationship exists between soldier's cardiac conditions and load-carrying

It must be pointed out that, except for the indirect physiological measures cited above, no medical studies have been found which support these observations.

K. Load-Carrying in Other Cultures

After other methods of easing the soldier's load-carrying burden have been exploited to their limits, it might be possible to approach the problem by training him to carry heavier loads. Examples of what might be achieved are seen in descriptions of burden-carrying by natives of other lands. Gray and Leary (15), for example, have summarized performance data in terms of weights carried over given distances, based on observations in several African regions. These data are presented in Table 4, and plotted in Figure 3.

While lacking in detail regarding sex, age, weight, height, duration of carry, and other related factors, and while probably less reliable than experimental data of this type would be, the data do suggest the wide range of loads able to be borne by African porters. Although such performance is not recommended as a goal for the combat soldier, the data suggest that culturally determined factors (and hence training) can at least partially affect performance of a task which is generally considered limited by physical constraints.

Table 4. Maximum Weight Carried and Distances Traversed From (15)

	Maximum Weights (Pounds)	Maximum Distances (Miles)
Southern Rhodesia	100	400
Northern Rhodesia	64	70
Nyasaland	100	50
Tanganyika	100	100
Kenya	250	30
Uganda	80	25
Mozambique	150	5
Ethiopia	225	10
Sudan	100	6
Liberia	125	25
Sierra Leone	84	--
Nigeria	160	35
Ghana	100	30
Cameroon	130	10
Congo	130	12
French West Africa	115	30
French Equatorial Africa	75	--
Gambia	40	2
Bechuanaland	20	--
Averages	113	52.8

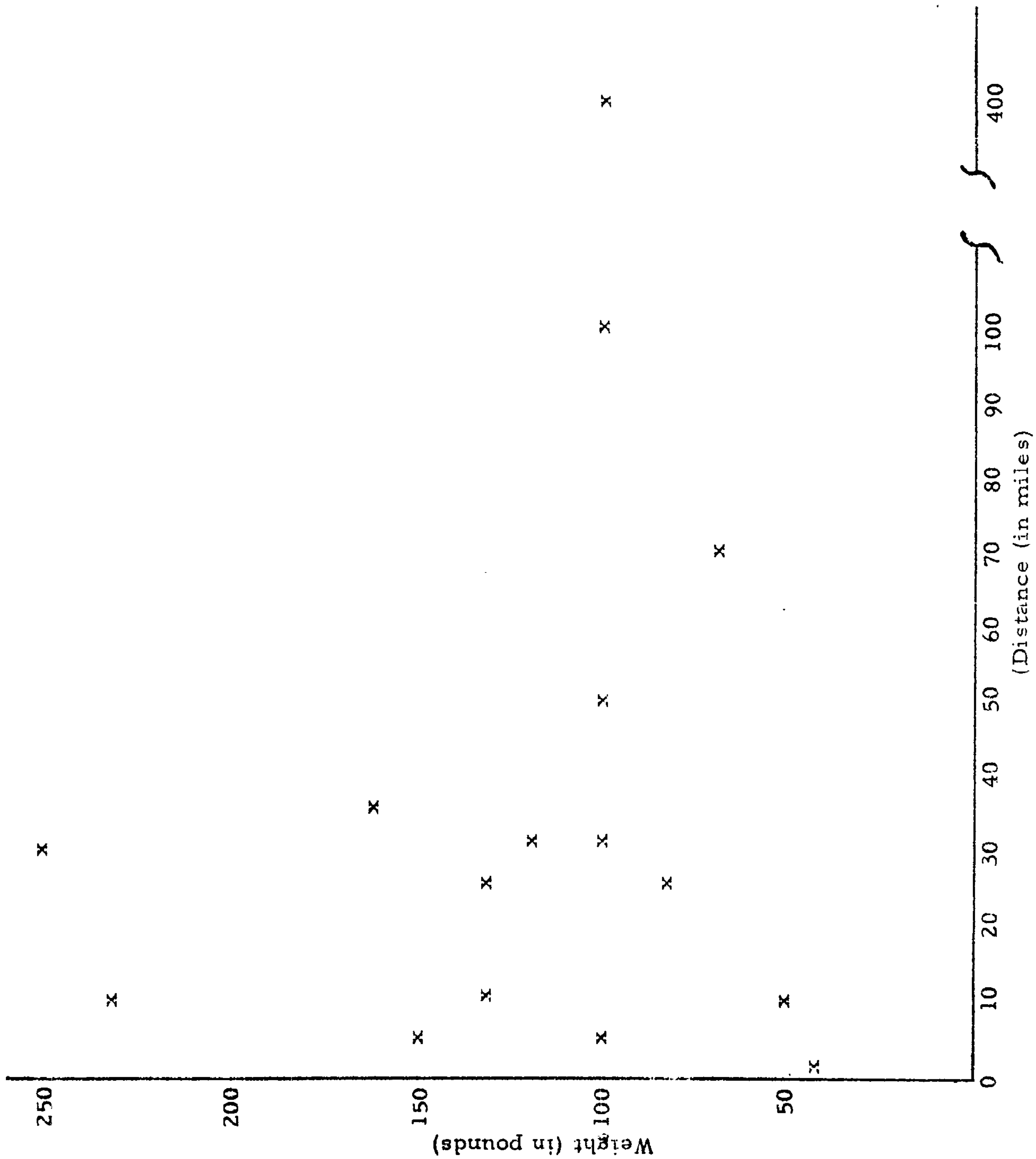

Figure 3. Maximum Weight Carried and Distances Traversed

L. Summary

The review of load-carrying literature has indicated the following:

1. Generally recommended maximum combat load is about 40 pounds for riflemen and 45 pounds for non-riflemen; generally recommended maximum marching load is about 55 pounds.

2. Actual combat loads being carried are reported to be as high as 62 pounds (for a rifle squad leader), and 77 pounds (for an M60 machinegunner).

3. Design of load-carrying devices can affect performance and subjective preferences; design recommendations drawn from a variety of studies have been presented.

4. Size and shape of loads have not been systematically studied; in any event, these factors are related to the types and design of the items being carried, as well as to the terrain conditions.

5. Low back carriage appears to be preferable to high carriage for most purposes and for loads above 46 pounds; thigh carry is undesirable; the Bell "Hip Pack" apparently has several important advantages.

6. Results of studies of a wide variety of specific load-carrying devices are presented; despite the fact that the jerkin has not been accepted for Army use, available data suggest several advantages in the jerkin concept. The T53-8 Experimental Pack has also proven effective.

7. Techniques for load-reduction include use of light-weight materials, special packs for special missions, use of multi-purpose equipment, training for survival with minimum equipment, and revamping of supply and logistics techniques to meet infantry requirements.

8. Reports of African porters carrying loads up to 150 pounds (and in some cases up to 250 pounds) suggests that training or use of novel techniques might facilitate load-carrying.

SECTION III

EQUIPMENT DESIGN

A. Introduction

This section is concerned with the effects of design of weapons, tools and equipment (other than load-carrying devices) upon performance. It should be noted that performance measures are usually related to many variables besides equipment design, and that it is often impossible to isolate specific design features responsible for improved or degraded performance. However, insofar as the studies which were reviewed described the task and environmental conditions and the specific design features of central interest, this information has been abstracted.

B. Equipment Design

Equipment is discussed here in the same order as presented in Appendix (B) (Handbook Summary), which presents additional data on each type of equipment. The original references may be referred to for fuller descriptions of the studies.

1. Canteen, Field

The canteen presently used by infantry personnel hits and rubs against the wearer's body while he is engaged in performance of various infantry tasks (51, 7). In addition, the "flopping" of the water-filled canteen is a problem, since the oscillation of water in the canteen is frequently out of phase with the motion of the body and tends to move freely in different directions (7).

Consideration might be given to the development of a new type of plastic canteen which can be rolled or folded up as its contents are consumed, so as to contain the remaining contents firmly. Present canteens could be contoured and padded so as to minimize frictional and rubbing effects against the wearer's body. Or, two thin, one-pint capacity, silhouette flask-type containers might be preferable to the bulky one-quart capacity container carried on the hip.

2. Containers, Ammunition

A review of the literature indicates that two fifty-pound containers are an optimal load for a single ammunition bearer, and that ammunition container weight should be limited to approximately 50 pound (23). In addition, it is recommended that maximum lengths for containers with end rope handles be 23 inches and that rope handles be placed in the middle of the box, with the handle eight inches above the cleat.(14). Also there is evidence that ammunition containers weighing up to thirty pounds can be lifted to heights of five feet by all personnel (10), and that lifting force decreases rapidly with increase in distance from frontal plane within which the lifting operation is attempted (62). Further, it is noted that when containers are carried by handles located on the sides and ends of equipment, transport time is increased (44).

3. Flamethrowers

Flamethrower design, for the most part, has not been covered in the available literature. The only available study concerned with flamethrowers attempted to determine differences in oxygen consumption while carrying two types of flamethrowers over short periods of time (21), and only negligible differences were found.

4. Grenade Launchers

Only one study appears to have been made of the effects of grenade launcher usage upon performance (54). Major results of this study were that the 40 mm grenade launcher, M 79, may be successfully utilized as a hand-held mortar (with the launcher butt held on the ground), and that with a multi-shot capability, the effectiveness of the M 79 would be greatly increased.

No studies have been found dealing with the effects of design and weight of the grenade launcher upon performance.

5. Hand Grenades

The combined results of several studies performed on the effects of grenade shape and weight (17, 19, 20) indicate that increased grenade weight, except for the two-ounce grenade, results in an accuracy decrement and that shape does not affect performance. Studies have also indicated that increasing thrower-target distance results in an accuracy decrement. One study concerned with the effects of grenade size upon performance (105-s) was not available for review at the writing of this paper. The effect of grip surface (which would seem to be an obviously critical design feature) does not appear to have been studied.

6. Helmets, Radio

One study has considered the effects of radio helmets (helmets with a built-in radio transmit-receive apparatus) upon some kinds of infantry performance (54). It was found that when using the radio helmet, there is a tendency to depend entirely on the radio rather than other control means (as, for example, hand signals). In addition, it was found that the radio helmet has no appreciable ballistic protective characteristics.

However, no study appears to have been performed to determine how peripheral and direct vision are affected by radio helmet use, over what noise range (in db levels) communications can be understood while using the helmet radio (as, for example, when receiving messages near a mortar firing), or the physiological effects of radio helmet use upon the audition of the user.

7. Machineguns

Evaluation of the 7.62 mm machinegun, M60, under conditions of simulated combat (54) shows that more than one man is required to service and operate the weapon effectively, that the M 60 ammunition belt causes many gun stoppages, and that when the M 60 is used in an automatic rifle role, mobility, and maneuverability of rifle squads are restricted.

8. Mortars

The design of mortars for portability is a widely recognized problem which needs more research attention (4, 55). Besides portability, other design features of the mortar appear to affect performance. This is perhaps best illustrated by results of a human engineering evaluation of the T 201 mortar (55), in which it was found that:

a. Rotator on the baseplate bound by fine dirt and had to be cleaned before operations could continue.

b. Rotator bound when hand pressure applied; may have been caused in part by dirt in rotator socket.

c. Dirt gets into rotator socket and bends tube ball.

d. Rotator socket chipped and burred and had to be cleaned; also, burrs were removed from pin slot on the socket.

e. Socket pin hard to use, especially at night and with mittens.

f. Wire cable in pin began to fray where it comes across top of pin.

g. Difficult for crew to get a smooth lifting action while removing misfires.

h. Elevating handle pushed into dirt when bipod is laid down.

i. Elevating handle turned down while carrying bipod to prevent hitting carrier in the groin.

j. When weapon was "dug in," the low setting on the tube was not needed for 800 mil elevation, only for 600 mil.

k. Collar is hard to remove from the barrel if frozen, since there is no projecting edge that can be struck.

l. Easy for a crew member to get his fingers pinched between recoil mechanism and the barrel or bipod.

m. Tendency to set the bipod too close to the baseplate when setting up or changing azimuth.

n. Traverse crank handle too small and consequently hard to operate, especially when wearing mittens.

o. Sight difficult to operate with mittens, especially cant correction knob.

p. Open sight on telescope sight not optimum.

q. Level bubbles on sight too sensitive..

r. Index line on traverse mechanism hard to see, especially at night.

s. Lock, which holds recoil mechanism to bipod, does not hold adequately.

The problems listed above indicate fruitful areas for future design improvement.

9. Pistols

Studies to determine the effects of pistol usage upon infantry performance have indicated only that use of a two-handed grip results in increased traget accuracy (47), and that pistol grip methods of support for other equipment should not be used for equipment weighing more than five pounds (9).

For the most part, however, the effects of design upon performance are not discussed in the literature. Considering the wide use of the .45 caliber pistol by infantry personnel (54), such studies would seem to be justified.

10. Radar, Hand-held

Only one study has been made of the effects of certain design features of a hand-held radar upon performance (9). This study, performed in the laboratory, was primarily concerned with methods of holding the radar unit. Results of this study indicate that with a more comfortable method of support, steadiness shows a marked improvement, that the neck strap support is preferred to the hand-held (pistol grip) mode, and that the pistol grip method of support should not be used unless radar unit weight can be reduced far below five pounds.

11. Rifles

The rifle is the primary shoulder weapon used by combat infantry personnel, and many studies have been performed to determine those design and weight characteristics of this weapon which influence performance. It has been found that:

a. Personalized rifle stocks do not affect marksman ship (35).

b. Sling usage during training improves performance (18).

c. Loop sling improves performance (44).

d. Rifle weight from 9.8 to 14.25 pounds has no effect on accuracy of firing from the prone position (42).

e. The configuration of the comb of the stock has no effect (25).

f. The upper limit recommended for recoil is 19.3 foot-pounds (41).

No studies appear to have been performed on the effects of rifle design upon various physical activities (running, jumping, "hitting the dirt," etc.). Further, the effectiveness of sighting with a rifle after engaging in fatiguing physical activity remains unexplored.

(Note: Though the M1 rifle has been largely replaced by the M14 rifle, research design data obtained for the M1 rifle may be directly applicable to the M14 rifle as well as to other rifle-type equipments.)

Discussions with members of the U.S. Army Special Warfare Forces indicated that the M1 rifle was too large and heavy to be used effectively by indigenous personnel of Southeast Asia. The M2 carbine, which is significantly lighter and shorter and has less recoil, might be a preferable weapon for the relatively short-statured, short-armed Southeast Asians. The advantages of a smaller weapon which is less likely to get caught in jungle thickets and underbrush, was also noted.

This suggests the desirability of special studies to determine optimum design features of weapons and equipment for nations receiving U.S. military aid. The anthropometric, behavioral, and physiological characteristics of some indigenous personnel vary markedly from those of U.S. troops. In addition, even U.S. troops may require specially designed equipment for guerrilla warfare in jungle terrain.

12. Rifles, Automatic

Research performed on automatic rifles appears to be concerned mainly with the U.S. Rifle 7.62 mm M14 (modified with bipod and hinged buttplate) and the Browning Automatic Rifle Cal. 30, M19. (54) While the research does not indicate much information about BAR design features affecting performance, the following conclusions were reported about the M14(M) rifle (54):

a. M14(M) overheats after firing less than 100 rounds at full automatic rate.

b. High cyclic rate of M14(M), coupled with instability, causes many gunners to become "gun shy."

c. Stability of M14 (M) is marginal when fired from a prone postion; M14 may be too light.

d. M14 (M) gunners, firing from hip to shoulder, experience difficulty in holding weapon on the target.

13. Rifles, Recoilless

Studies performed on the recoilless rifle seem to indicate that weight and design of recoilless rifles do influence performance. It was found that the crew of the M67 recoilless rifle were unable to keep pace with the remainder of the rifle platoon and that the M67 rifle seriously restricts maneuver and movement of the unit. Since the M67 recoilless rifle weighs 44 pounds, it may be assumed that weight is one major factor affecting performance. Also, it was found that all gunners using the M72, Light Anti-tank Weapon, which weighs 4.5 pounds, achieved direct hits at a range of 135 to 145 meters. Evidently some feature of the weapon is influencing performance. Reported results of the above studies are too general and sample sizes are too small for any firm conclusions to be made.

Results of another study indicate that the orientation of a target with respect to terrain and background exerts a strong influence on the direction and magnitude of errors made while firing at a target with an M20 Rocket Launcher (49).

14. Tool, Entrenching

Studies attempting to determine the optimum location for the entrenching tool on the wearer's body have been inconclusive. One study (7) indicates that when the entrenching tool is located on the pack, it swings and bounces less than when it is fastened on the wearer's belt. However, another study (11) notes that the entrenching tool bounces against the head and neck, frequently displacing the helmet. A third reference (280-s) notes that a significant improvement in the standard U. S. Infantry individual load-carrying equipment is to have "... the entrenching tool carrier... carried on the pistol belt."

15. Tripods, Bipods and Equipment Supports

Results of studies concerned with tripods, bipods and other equipment supporting devices indicate that equipment legs frequently brush or hit against objects while in transit and impede movements of equipment bearers (39, 54). Other studies indicate that equipment support devices (bipods) are difficult to carry because of large, inadequate shaped handles and a one-ended center of gravity (55). Also of interest is a study which notes that an M60 machinegun with a tripod consistently outfires the M60 on a bipod (54). The third leg of the tripod evidently furnishes additional stability during firing.

C. Summary

Studies of equipment other than load-carrying devices (i.e., weapons, tools, etc.) have been reviewed to identify design features affecting performance. The results are presented in the Handbook Section (Appendix B), where they are grouped by type of equipment. Major conclusions are presented below.

1. The rifle has been more extensively studied than any other type of equipment.

2. Studies of marksmanship performance with the M1 rifle indicate that:

   a. Performance is improved by:

      1) Loop sling (as compared with other slings)

      2) Use of sling during training

   b. Performance is unaffected by:

      1) Rifle weight from 9.8-14.25 pounds (when firing from prone position)

      2) Use of personalized stocks

      3) Configuration of the comb of the stock.

   c. Upper limit recommended for recoil is 19.3 foot-pounds.

3. The weight of the M67 recoilless rifle (44 pounds) hinders mobility of the rifle crew.

4. Indigenous personnel of Southeast Asia prefer the M2 carbine, which is shorter and lighter than the M1 rifle.

5. Soldier maneuverability as a function of rifle size and weight has not been studied (except for the M67 recoilless rifle), nor have the effects of prior load-carrying upon marksmanship.

6. Equipment evaluation of the T201 mortar revealed many design deficiencies, several of which would presumably hinder set-up and maintenance, as well as operation. These deficiencies are noted to focus design attention on an area requiring significant improvement.

7. The effects of human engineering design features upon performance, for other types of infantry equipment, have not been studied to any appreciable extent.

8. Design requirements of indigenous personnel have not yet been determined, nor have the requirements of U.S. troops in guerrilla warfare in jungle terrains.

SECTION IV

PERFORMANCE MEASURES

A. Introduction

Determining the effects of load and equipment design upon infantryman performance is complicated by the problems inherent in measuring "performance." From a systems viewpoint, the criterion of infantry performance can be expressed in terms of kills per unit cost, and for certain types of measured activities (such as rifle marksmanship), there is at least a face validity basis for asserting a relationship to this criterion. Other commonly measured activities (such as running speed, energy expenditure, and preferences) are difficult to relate to kills per unit cost; the relationship is based on the assumption that "poor" performance is somehow correlated with reduced kills or increased costs, but the degree of correlation is certainly not explicit.

Performance requirements of equipment, as described in Military Characteristics, are usually given priorities, and in the absence of other criteria, it is probably justifiable to regard these as guidelines in determining the appropriate activities to measure in evaluating equipment design. Thus, in addition to such obvious measures as range, firing rate, and other criteria which might be explicitly specified, the increasing emphasis on such factors as mobility, rapid set-up time (for crew-served equipment), and maintainability will usually suggest other appropriate measures of performance.

Initial selection of performance measures is only part of the problem, however. To identify measures which are likely to be sensitive to the particular design features of interest, as well as related to the mission or performance requirements of the equipment, requires both scientific and military intuition and experience. Negative (i. e., non-significant) results in a laboratory experiment could mean either that the measure was insensitive or that the design variable was unimportant. In a field test situation, the measures are usually contaminated by the effects of weather, terrain, clothing, other equipment, level of training, and skill of observers (when observer ratings are used). And in any test of man-machine performance, the effects of attitude (general level of motivation, confidence in or preference for specific equipments) are difficult to identify and control.

In this section, the various types of measures employed in the studies which were reviewed will be discussed, and recommendations will be made for increasing the comprehensiveness and validity of measurements in future research. For the convenience of the reader, Appendix A presents a Rapid-Reference Guide showing types of activities measured in evaluating various items, and reference numbers of the studies.

B. Types of Measures

The measures employed in the various studies reviewed can be categorized along at least two dimensions: 1) type of activity or behavior, and 2) techniques of measurement. Although the categories within each dimension are far from distinct, they are convenient for purposes of discussion.

The major types of activity or behavior which have been commonly "measured" include the following:

1. Physiological and medical effects (e.g., pulse rate, temperature, respiration, skin irritation, tremor, etc.).

2. Mobility and maneuverability (e.g., running, jumping, crawling, taking cover, etc., usually while carrying equipment loads).

3. Performance of specified tasks with the equipment (these would include both "primary" tasks such as rifle shooting and throwing hand grenades, in which the equipment is used to accomplish its prime purpose, and "secondary" tasks such as loading, set-up operations, etc.).

4. Indirect inferences about performance. This category includes the more basic research studies performed in laboratories (such as weight-lifting, force-exertion, crank-turning), usually in the absence of the specific tactical equipment; results of such studies are often used as standards against which equipment is later evaluated (in various stages of design) without actually conducting performance tests.

Techniques of "measurement" within each of the categories mentioned above, can take a variety of forms. For convenience of discussion, three categories may be identified:

1. Relatively objective measures (e.g., data such as time, distance, number of errors, etc., or recorded on film, paper, etc.).

2. Observer ratings (relatively structured in format) or reports (relatively unstructured).

3. Subjective ratings, preferences or reports.

The discussion which follows is organized according to the various types of activities measured; measurement techniques employed are described and evaluated in each case.

1. Physiological and Medical Effects

Perhaps more than any other category of activity, physiological and medical effects lend themselves to objective and precise measurement techniques, and hence have been frequently used in laboratory studies. These activities are most commonly measured in conjunction with other activities (e.g., marching, running, walking a treadmill) while load-carrying; other frequent applications have been in conjunction with rifle-firing (reports and tests of hearing loss, reports and observations of redness and swelling of skin due to recoil), and in evaluating load-carrying devices (observed skin irritation due to strap pressure).

For the most part, physiological measures have not been systematically correlated with other (behavioral) performance measures. Although the studies reviewed here give no evidence of negative correlations, the physiological measures (except for strap pressure irritations) tend to be less sensitive to minor variations in design than other performance measures. However, there is evidence that measurement of energy expenditure is extremely sensitive to loads carried on the thigh, and recommendations against thigh carry have been made on this basis.

In general, such things as energy expenditure and oxygen consumption vary as would be normally expected with load, speed, distance, etc.

In summary, although most physiological measures lend themselves to objective and precise measurement techniques, and are sensitive to load weight, their validity is questionable as a measure of performance unless supplemented by other behavioral measures. Easily observed medical effects such as skin irritation are useful measures for limited purposes. Longer range medical effects, such as latent heart diseases or backstrains, have not been systematically studied in relation to load-carrying or equipment design.

2. Mobility and Maneuverability

The activities measured most frequently in the studies reviewed here are those related to mobility and maneuverability of the soldier. Marching, running, jumping, climbing, traversing an obstacle course, and various combinations of these in sequence, often in conjunction with measures of physiological activity, have been used as the basis for evaluating load, load-carrying devices and individual items of equipment in a pack. Subjective questionnaires and structured ratings by observers are the most common measurement techniques, although time and motion analysis, sometimes made from filmed records, have also been used.

Although these tasks are typical of the activities performed by foot-soldiers, they are relatively gross segments of behavior, affected by many variables which are difficult to control. Perhaps for this reason, the more objective measures tend to be relatively insensitive to the variables being investigated, and more reliance is usually placed on the subjective preference reports and observer ratings. It should be noted that these measurement techniques are usually less valid than objective measurements, particularly when the test situation is such that no direct comparison between two methods is possible.

Use of more rigidly controlled experimental techniques could improve the reliability of observer reports, even when these measures are obtained under field conditions. A few principles which could be easily applied in most field tests are listed below:

a. Multiple observers should be used, and their consistency reported.

b. Immediate comparisons should be made of one variable (e.g., equipment, pack, design feature, load) with another.

c. Variables should be presented either randomly or in counter-balanced trials.

d. Observers should be unaware of the deliberately varied factors affecting the performance they are observing.

e. Observers should be trained, tested and screened for ability to detect small differences in performance.

Another technique for increasing the value of activity measurements such as these, is to combine them with objective measures of tasks in which other equipment is utilized. For example, the differential effects of two load-carrying devices might be measured in terms of rifle-firing accuracy after marching, crawling, etc., with each of the devices. (See below for a fuller discussion.)

3. <u>Performance of Specified Tasks with Equipment</u>

a. <u>Primary Tasks</u>

The tasks required in accomplishing the primary purpose of an item of equipment are, of course, the most obvious kinds of activities to measure. Measuring the accuracy of firing rifles and pistols, throwing grenades, aiming hand-held radars, etc., as a function of design variables, has at least face validity, and in many of the studies reviewed here, gives results which are sensitive to the variables of interest. In studies of load-carrying devices (such as jerkins), one of many useful activity measures would be expected to be the speed with which various items could be removed, but this measure has not been reported sufficiently to assess its sensitivity.

One of the problems associated in the use of these activity measures is that the performance of highly trained soldiers is likely to be unaffected by gross variations in design, when the task is performed under relatively easy conditions. As an example, accuracy of rifle fire was found to be insensitive to changes in weight from 9.8-14.25 pounds, when the task was to fire from prone position (42). Results such as this do not prove that rifle weight will have no effect on performance under combat conditions. Hence, equipment evaluators generally obtain subjective reports of preference along with objective measures of performance, and often base their conclusions on these preference measures.

In laboratory studies, significant differences in performance are sometimes forced by arbitrarily increasing the difficulty of the task. There is a good deal of justification for doing this when conducting field tests of infantry equipment, because of the normally expected increase in task difficulty under combat conditions. Thus, one way of increasing the sensitivity of measures of (for example) firing accuracy would be to require the activity to be performed during or after the strenuous physical activities of running, crawling, etc. This was not done in any of the studies reviewed, although in one study (34) measures of rifle aiming steadiness (which might be related to firing accuracy) were obtained after exercise. In other work performed by the U.S. Army Infantry Human Research Unit,[1] measures were obtained under simulated combat conditions using moving targets to increase task difficulty. Not enough data of this type have been obtained with varied design features to permit an assessment of the validity of the method, but it appears promising and deserves further investigation.

b. Secondary Tasks

Despite the obvious face validity of primary task measurement, the measurement of secondary tasks (as defined earlier) offers the advantage of a much wider selection of activities for most equipment evaluations. Canteens, ammunition pouches, intrenching tools, etc., must be carried as well as used. Rifles and other weapons must be loaded as well as fired. In particular, crew-served equipment must be emplaced, assembled, sometimes cabled, and (perhaps most important) checked, repaired and calibrated.

Carrying of small items has frequently been employed as an activity measure, but in almost all cases the results have been interpreted from the viewpoint of design of the carrying device rather than of the item. Weapon loading has been utilized as the activity to be measured in a surprisingly few studies, considering the relatively direct relationship between loading speed and kills per unit cost.

Perhaps the most important potential application of secondary task measurement is in the case of crew-served equipment, which is likely to be more complex in design and therefore more difficult to set up and maintain, than equipment for the individual soldier. The variety of secondary tasks which must be performed with such equipment before the primary task can be accomplished, is illustrated in Table 5, which shows some of the subtasks required to operate an electronic guidance system unit. The speed and accuracy with which tasks such as these are performed, and the variability of the measures obtained, are likely to be importantly related to higher-order criteria of infantry performance, as well as being extremely sensitive to small variations in design. The use of task-equipment analysis techniques in the early stages of design can help identify these tasks sufficiently in advance so that evaluative studies can be performed in the laboratory (with simulated components) before

[1] Personal Communication: Dr. T. F. Nichols, USAIHRU.

rather than after the equipment design has been finalized. Use of motion picture film records and time and motion analysis techniques are appropriate to many of the activities involved, and add to the precision of the measurements.

Only one of the studies reviewed here (55) makes use of this type of activity measurement, in comparing two types of mortar, and the results suggest that these measures are more sensitive to design variables than measures of carrying time, despite the fact that one mortar weighed almost twice as much as the other. Many more studies of this type are necessary, in which more specific identification is made of the advantageous design features, before generalized conclusions concerning design features can be drawn.

Table 5. Some of the Tasks Required to Prepare a Typical Electronic Guidance System for Operation

a.	Sets computer at designated operating point
b.	Removes separate cables from stowage
c.	Orients cables
d.	Connects cables
e.	Checks all voltage inputs
f.	Receives horizontal approach angle and dive angle setting
g.	Sets both angles in the computer
h.	Nulls on target
i.	Checks indicator panel

4. Indirect Inferences About Performance

In some of the studies reviewed, the term "equipment evaluation" best describes one of the evaluative techniques employed. Essentially, this implies that a trained observer reviewed the design of the item apart from its actual usage, and made inferences about its performance by comparing it with implicit or explicit design standards. Ideally, these design standards should be based on sufficient data, obtained under varied but controlled conditions, to permit generalizations.

Design standards based on experimental study are available in many forms, but they have been applicable primarily to design of equipment with sophisticated display and control subsystems. The Handbook Section of this report (Appendix B) represents a first attempt to assemble data applicable to infantry equipment. The data available have proven to be applicable primarily to the weight and location of loads and the design of load-carrying devices; some data relate to weapon design, but are not sufficient for making more than a few design generalizations. Little if any data relate directly to design of other items of equipment.

It must be concluded, therefore, that not until the data presented in this Handbook have been considerably supplemented, will equipment evaluation alone be a reliabile technique for evaluating more than a few infantry items.

C. Summary

The types of activities and methods of measurement employed in the studies reviewed in this report have been categorized and evaluated.

Physiological activity and medical effects, although widely used and relatively precise, remain for the most part uncorrelated with other behavioral measures. They are sensitive to variations in weight, and to certain specific design features such as strap pressure, but not to other subtle design variables.

Gross bodily activities related to mobility and maneuverability are the most commonly employed tasks, measured objectively, through observer ratings and subjective reports, and often supplemented by measures of physiological activity. They are useful in evaluating load, load-carrying devices and items carried in packs. The objective measures tend to be contaminated by uncontrolled variables; observer ratings could be made more reliable if principles of experimental design were followed.

Activities related to the primary purpose of the equipment have been used most frequently in evaluation of weapons (e. g. , firing accuracy). With

highly trained subjects, such measures may not be sensitive to minor design variations unless the task is made more difficult by combining it with maneuvering activities or load-carrying. Secondary tasks (e.g., set up, calibration, maintenance) assume major importance in the case of crew-served weapons, and should be more extensively measured. Task-equipment analyses can help identify the critical tasks, and time and motion study can aid in obtaining precise measures.

Equipment evaluation in the absence of performance measurement has limited application for infantry equipment, due to the inadequacy of data on which to base design standards. The Handbook Section of this report is a first attempt to collect applicable data for this purpose.

SECTION V

RESEARCH PROBLEMS

A. Introduction

The literature review has identified the types of studies performed and results obtained to date. Gaps in present knowledge have been pointed to in the other sections of this report.

In this section, the implications for future research will be presented.

B. Load-Carrying

1. Maximum Loads

Although recommendations regarding maximum loads to be carried have been based primarily on observational reports, or on physiological measures which are difficult to relate to other behavior, the recommendations all tend to cluster around the value of 40 to 45 pounds for combat loads and are consistent enough to constitute an order-of-magnitude guideline. In view of the evidence that present combat loads substantially exceed these recommended values, it would appear that research effort might better be expended in the area of load-reduction, than in attempts to verify the "maximum load" figure. Use of indigenous burden-carriers, animals and wheeled-vehicles should be explored, as should the concept of "special loads for special missions." The metabolic cost of load-carrying can be reduced by decreasing velocity of progression, but this is likely to prove costly in terms of combat effectiveness. From the infantry point of view, it would be worth exploring radically new techniques of supply and logistics to help reduce the load on the foot-soldier.

Two other points should be made:

a. In any future studies of maximum load, standardized performance tasks, which can be objectively measured, should be used in addition to observations of soldier maneuverability. Rifle or pistol firing at moving targets, during and immediately after load-carrying, might be one such task. The measures obtained are likely to be sensitive to the loads, terrains, or other variable conditions under which the load-carrying was performed, and would be directly related to a significant criterion of infantry performance.

b. Observer reports of load-carrying capability in other cultures suggest that training, or the use of novel carrying techniques, might facilitate load-carrying. The reports are suggestive enough to justify some research attention.

2. Design of Packs and Other Load-Carrying Devices

Although several guidelines to the design of load-carrying devices can be drawn from studies to date, this is a problem area that needs further intensive study. With few exceptions, the kind of data available do not permit detailed design specifications to be developed. Subjective preferences for certain types of packs might be used to develop hypotheses about specific design features, which could then be investigated experimentally. In particular, the design advantages apparently inherent in the British Battle Jerkin might form the basis for an acceptable item for U. S. troops.

Research on load-carrying devices cannot be isolated from research on design of the items carried. There is a preponderance of work in which packs are evaluated in terms of how well they accommodate the items carried. Too little attention has been devoted to accommodating the design of the items to the requirements of load-carrying. The latter problem area desperately needs research support.

C. Equipment Design (other than load-carrying devices)

With the exception of the rifle, very little research has been performed on the design of infantry equipment. For items carried in packs, research should be aimed at developing new designs which facilitate carry as well as performance (see above). For crew-served equipment, accomplishment of secondary tasks (such as set-up and maintenance) are important performance criteria, and task-equipment analysis can help identify the activities which might form the basis for task measurement in such studies.

Two of the most critical areas for research have been generated by the recent requirements for use of U. S. troops on special missions, and by the possible future requirements for increased emphasis on jungle or guerrilla-type warfare:

1. The supply and training of native troops could be facilitated by recognition of the fact that tools, weapons and equipment for their use must be based on requirements unique to their anthropometric, behavioral and cultural characteristics. Basic data are needed for this purpose.

2. The specialized mission requirements imposed on U.S. soldiers overseas suggest advantages in tailoring equipment designs to these special needs. On the other hand, there are likely to be significant cost advantages inherent in the concept of multi-purpose equipment and weapons. What seems to be required is a series of trade-off studies, in which the special- and general-purpose design concepts are compared for a variety of equipment types, taking into account not only the mission, task and environmental requirements and cost, but also the weight, size and other load-carrying requirements likely to be imposed.

D. Performance

From the methodological viewpoint, there are several areas which could benefit by research attention. One of these, although perhaps not the most important, would be a systematic effort to correlate measures of physiological activity with other behavioral aspects of performance such as weapons firing, maneuverability, assembly and checkout of crew-served equipment, etc. Physiological measures have the advantage of being relatively precise and objective, but they cannot be used with confidence to predict other behavior.

A more important area for methodological study is the problem of obtaining reliable and valid measures of performance during simulated (and perhaps real) combat conditions. The realism which can be introduced into field studies is valuable in identifying critical factors affecting performance, but the factors which can be identified by the use of observer ratings tend to be rather gross. It would be useful to extend the use of experimental procedures as much as possible to the field test situation, and to develop methods of selecting and training observers and of furnishing them with procedures which would enhance the value of their ratings or reports. Although obtaining useful data from actual combat situations is admittedly more difficult, some of the benefit of this type of research might even extend to combat observations.

Finally, the more general problem of what constitutes criteria of good infantry performance cannot be ignored. Intermediate criteria such as marksmanship, agility, load-carrying, and even physiological activity measures, will undoubtedly continue to be employed. But they could be more meaningfully interpreted if their degree of relationship to each other and to some ultimate measures of performance of the infantry as a total system could be developed. The question "How much added firing range is a sore shoulder worth?" may seem cold-blooded, but it needs to be asked.

The first step would require a broad-gauge operations analysis approach (which may in fact be in progress, although not covered in this review) to develop infantry system criteria, and to continually revise and update them as mission requirements change. But the following steps would require lengthy and painstaking research, combining analysis, field test and laboratory study, aimed at relating a variety of specific infantry activities to these broad criteria. Although such a program is perhaps too lengthy and costly to be undertaken as a package, an awareness of the nature of the problem will help researchers and Army personnel to interpret test results in proper perspective, and perhaps to contribute insights from time to time which may eventually provide a foundation for such a study.

APPENDIX A

RAPID REFERENCE GUIDE

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RAPID REFERENCE GUIDE

This Appendix contains a Rapid Reference Guide for designers of hand-carried or man-ported combat infantry equipment, for research scientists interested in determining what research studies have been performed on hand-held, - carried, or - operated equipment units, and for Army personnel interested in obtaining detailed information regarding task performance with specific items of equipment.

The Guide lists equipments studied and activities measured in the studies. Reference numbers refer to literature references listed in Appendix C of this Handbook.

A designer interested in designing a light-weight mortar might first look under the EQUIPMENT column until he comes to the heading MORTAR; he would then look across the MORTAR row and note that four references are concerned with mortars. He could then refer to Appendix C of this Handbook to see references corresponding with given reference numbers. If he is concerned with design problems involved in loading mortars, he may select only that reference listed under the TASK/ACTIVITY; LOADING A MORTAR.

In a similar fashion, Army personnel interested in determining how marching is affected by the tools carried by the infantry soldier would refer first to the TASK/ACTIVITY list, look across this list until he came to the title, MARCHING, and then refer all those references associated with given equipment units. For example, he is interested in determining how marching is affected by the intrenching tool or the relationship existing between a soldier marching and his intrenching tool, he would look down the MARCHING column until he came to the reference number associated with TOOL, INTRENCHING. As in the above case, he would then refer to Appendix C of the Handbook to see which references correspond with the reference number.

EQUIPMENT	AGILITY (RATING)	BALANCE (RATING)	CARRYING AMMUNITION CONTAINERS	CARRYING FLAMETHROWERS	CHANGING DIRECTION	CLIMBING	CRAWLING	CREEPING	DESCENDING	DONNING & DOFFING PACKS & EQUIPMENT	FALLING AND GETTING UP	FIRING AN AUTOMATIC RIFLE	FIRING A GRENADE LAUNCHER	FIRING A MACHINE GUN	FIRING A PISTOL	FIRING A RECOILLESS RIFLE	FIRING A RIFLE	GENERAL PHYSICAL ACTIVITY	HAULING EQUIPMENT	
CANTEEN, FIELD											7									
CONTAINERS, AMMUNITION			14, 23																	
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FIRING A PISTOL	FIRING A RECOILLESS RIFLE	FIRING A RIFLE	GENERAL PHYSICAL ACTIVITY	HAULING EQUIPMENT	JUMPING	LIFTING AMMUNITION CONTAINERS	LOADING A MORTAR	LOADING A RIFLE	LOADING-UNLOADING BREN MAGAZINES	MARCHING	MORTAR PORTAGE	OBSTACLE COURSE	OPERATING HAND-HELD RADAR	PRODUCING EQUIPMENT	PULLING A SLED	ROLLING	RUNNING	RUNNING AND CLIMBING	RUNNING DOWNHILL	RUNNING, JUMPING AND CLIMBING	RUNNING STAIRS	SETTING UP A MORTAR	SHOVELLING SAND	THROWING HAND GRENADES	TRANSMITTING-RECEIVING FIELD COMMUNICATIONS	TRANSPORTING ELECTRONIC EQUIPMENT
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APPENDIX B

HANDBOOK

APPENDIX B

HANDBOOK

This Appendix presents the results of the literature survey summarized in tabular form. This format was developed so that the equipment designer, researcher, or interested Army personnel could readily see the results of a number of different research projects studying a specific type of equipment.

If an equipment type has not been specified in this Handbook, it is quite likely that little to no research has been performed on the effects of design of such an equipment on task performance of the combat soldier. For example, a cursory survey through the list of equipment below indicates that the bayonet is not included. This means that bayonet design as it affects task performance of the combat infantryman has not been reviewed or researched in the field or laboratory, or that results of such a project, if conducted at all, have not appeared in the available literature. Hence, by omission, future areas for equipment design research may be inferred.

In addition, in a number of instances, the operational status of some equipment types, especially load-carrying devices, are unknown.

The tabular material is arranged by equipment type as follows:

1. Canteen, Field
2. Containers, Ammunition
3. Flamethrowers
4. Grenade Launchers
5. Hand Grenades
6. Helmets, Radio
7. Load-carrying Devices - General

    a. Ammunition Pouches
    b. Bamboo Pole
    c. Chest Carry
    d. Jerkins
    e. Korean A-frame
    f. Packboard
    g. Packs, Miscellaneous
    h. Rucksacks
    i. Sleds

j. Slings and Bandoleers
k. Swiss Combat Clothing Ensemble
l. Thigh Carry
m. United Kingdom Z. 2 Pack
n. United States Experimental Pack T53-8
o. Vests
p. Waist Carry
q. Wheeled Carts

8. Machine Guns
9. Mortars
10. Pistols
11. Radar, Hand-Held
12. Rifles
13. Rifles, Automatic
14. Rifles, Recoilless
15. Tool, Intrenching
16. Tripods, Bipods, and Equipment Supports

The following data are provided for each equipment heading:

1. Task/Activity

The task or activity in which the soldier or subject was engaged while carrying, using, or manipulating the equipment unit under discussion is given.

2. Equipment/Load

The specific unit of equipment or load and its weight are given. Weights of individual equipment units as well as weights of total loads are given, if available.

3. Mode

The mode of carrying, lifting, or manipulating given equipment units is given. Generally, this indicates that portion of the body (shoulder, back, hip, or other body region) on which the given equipment unit or load is carried, affixed, or in closest proximity.

4. Conditions

Conditions of terrain, mode of hiking, combat-non-combat, whether in the laboratory or field, are given when available.

5. Activities Measured

Measures such as time, preference, or physiological measures used in the research project are specified.

6. Results

The results of the experiment, field assessment, observation, or research project are presented. Emphasis has been placed on those results which indicate the effects of equipment design or weight carried upon the performance of the combat infantryman. The reader, therefore, should refer to the specific study for the complete summary of results.

7. References

The given reference numbers are associated with specific literary references given in Appendix C of this Handbook.

Equipment CANTEEN, FIELD

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Falling and Getting Up Marching Obstacle Course Running Stairs	Canteen with water Weight: 3-1/2 pounds	Attached to load-carrying component near hips	(Field) Marched on treadmill at 2.5, 3.5, and 5.0 mph Subjects ran obstacle course, hit the dirt, and ran up stairs	Physiolcgical measures Time to run obstacle course Stroboscopic analysis of pack and component equipment motion Subjective measures	Flopping of water-filled canteen is a problem with all load-carriage systems Subjects complain that canteen hits against body	7
Marching	Canteen in carrier worn on pistol belt Weight of canteen, carrier, and belt; not specified	Worn on pistol belt	(Field) Canteen carrier attached to belt by: a) Double end hook b) Two double end hooks c) Clamp-on clip	Observation and interrogation	All methods unsatisfactory Canteen rubs against wearer	52

Equipment CONTAINERS, AMMUNITION

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Carrying Ammunition Containers	Ammunition Container Weight: 50-80 pounds	Carried by handle on shoulder, or slung across shoulder	(field) Transported ammunition between to points 150 yards apart	Time to carry ammunition	Two 50-pound containers are an optimal load for a single ammunition bearer. Ammunition container weight should be limited to approximately 50 pounds	23
Carrying Ammunition Containers	Boxes, general purpose Weight of boxes: 10-14 pounds Weight of total loads: 12-102 pounds	Carried by rope handle	(Field) Carried boxes, 20-26 inches in length, over hard, flat terrain, and over slightly inclined gravel terrain	Not fully specified	Recommand that rope handles be placed in middle of box. Recommend that rope handles be 8 inches in length above cleat of box. Recommend that maximum length for boxes with end rope handles be 23 inches	14
Transporting Electronic Equipment	Electronic Equipment Unit Weight: 39-66 pounds	Carried by handles located on sides and ends of equipment	(Field) Carried electronic equipment cross-country, up slopes, in snow and mud	Time to transport equipment	Two-man equipment carry not feasible over terrain used; increased transport time by 3-5 minutes. (However, handles useful for short carries of equipment... 50 feet or less).	39

Equipment CONTAINERS, AMMUNITION (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Lifting Ammunition Containers	Loaded Ammunition Boxes Weight of empty box: 7 pounds Weight of total load: unspecified	Lifted	(Laboratory) Lifted ammunition cases of varying weights to platforms 1-7 feet above floor	Heights above floor weights were lifted	As height of platform increases, weight lifted decreases Entire sample able to lift to a height of 5 ft. Large decrease to be expected when arms rather than legs become crucial in performing work	10
	Weight/load: Not specified	Lifted horizontal bar	(Laboratory) Exerted steady, maximum lifting force on horizontal bar placed in a frontal plane for 3 seconds	Force exerted by feet on surface of force analysis platform	Effect of grasp (overhand or underhand) is small Effect of lifting action (derrick or knee) not marked Force decreases rapidly as distance of feet from frontal plane increases Maximum lifting force decreases with increase of grasp height	62

Equipment CONTAINERS, AMMUNITION (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Lifting Ammunition Containers	---	---	Spring scale attached to extremity under test, load applied until subject no longer able to maintain initial position.	Breaking strength	Neck extension strength is 5 times neck flexion. Ankle is strongest joint of body; slightly stronger in flexion than extension. Arm and shoulder strength very poor when arm extended outward; especially weak in overhead position.	30

Equipment FLAMETHROWERS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Carrying a Flamethrower	M-1A1 flame-thrower with gun, filled to specification Weight: 60.5 pounds E-2 flamethrow-er filled to specification Weight: 69.5 pounds E-2 flamethrow-er with fuel removed Weight: 60.5 pounds	Carried on back	(Laboratory) Marched at 3.5 mph on level treadmill; rose from lying on stomach to stand-ing position and lying down twice per minute with flamethrowers on back	Physiological measures	Differences in oxygen consumption for carry-ing two types of flame-throwers very slight over short time periods. Fully loaded E-2 flame-thrower definite meta-bolic load (5% addition to total metabolism) compared to fully loaded M-1A1 outfit.	21

Equipment GRENADE LAUNCHERS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a Grenade Launcher	40 mm Grenade Launcher, M79 Unloaded weight. 6-1/4 pounds	Fired from shoulder and with launcher on the ground	(Field) Fired under conditions of day and night visibility	Hits per target Ammunition expenditure	M79 may be successfully utilized as a hand-held mortar (butt on ground). M79 with multi-shot capability would more than double its effectiveness.	54

Equipment HAND GRENADES

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Throwing Hand Grenades	Spherical shaped grenades Weight: 12, 15, 18, 21 and 24 oz. Standard grenades Weight: 12, 15, 18, 21 and 24 oz. Tear drop-shaped grenades Weight: 12, 15, 18, 21 and 24 oz. Cylinder shaped grenades Weight: 12, 15, 18, 21 and 24 oz. Wooden grenades filled with lead Weight: 2, 4, 6, 8, and 10 oz.	Thrown overhand	(Field) Grenades thrown at distances 10-35 yards from target	Accuracy	Increasing thrower-target distance results in decrement in accuracy. Weight increase results in decrement in accuracy. Shape does not affect performance. With exception of 2-oz. greande as weight increases, accuracy decreases. Grenade throwing for accuracy performed as well with a pack as without a pack. Greande throwing when carrying U. S. Experimental Pack was more accurate than when carrying U. S. Standard Pack or British Experimental Pack.	17 19 20

Equipment HELMETS, RADIO

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Transmitting and receiving field communications	Helmet radio Weight not specified	Worn on head	(Field) Simulated combat conditions	Mission evaluation Tactical evaluation Evaluation of equipment and material	Helmet radio worn rather than carried. Receiver always positioned near ear. Weighs less than AN/PRC-6. Greater tendency to depend entirely on radio than other control means. Has no appreciable ballistic protective characteristics. Battery life is unchanged. Only one frequency is available at a time.	54

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching and Fighting	Combat load	Carried on back	Combat	---	Forty-one pounds optimum load for combat.	148-s
Marching and Fighting	Combat load	Carried on back	Combat	---	Soldier's carrying capacity never to exceed 45 pounds.	*
Marching and Fighting	Combat load	Carried on back	Combat	---	Forty pounds recommended as combat load to be carried by rifleman under most trying conditions.	51
Marching and Fighting	Combat load	Carried on back	Combat	---	Forty-five pounds recommended as combat load to be carried by combat soldiers, other than rifleman.	51
Marching	Combat load	Carried on back	Combat	---	Fifty-five pounds be adopted as load to be carried by any soldier when march conditions prevail.	51
Marching and Fighting	Combat load	Carried on back	Simulated combat conditions	Many and varied	Recommend that load of infantry soldiers be limited to 45 pounds.	54
Marching and Fighting	Combat load	Carried on back	Simulated combat conditions	---	Recommend that 40 pounds be recognized as maximum efficient combat load.	24

* Note: Personal Communication: H. E. Kelly, Advisor, U. S. Army Infantry Human Research Office, Ft. Benning, Ga.

Equipment LOAD-CARRYING DEVICES: GENERAL (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching and Fighting	Combat load	Carried on back	Literature review	---	Optimum load weight figures should be 30-40% of body weight (or from 46-62 pounds).	99-s
Marching	Not specified	Carried on back	Literature review	Physiological	Energy expenditure increases when weight load is increased beyond 40% of body weight (or beyond 62 pounds).	12-s
Marching	Army 5-gallon water can weighted with sand and mounted on plywood packboard	Carried on back	Marched 1-1/4 miles at 2.5 mph over desert terrain	Physiological	Forty pound pack carried at a rate of 2.5 mph continuously for 1/2 hour appears to represent extreme upper load limit to carry in any sandy area on desert.	8
Pulling a Sled	Total load 75-218 pounds	Pulled	Pulled sled over level snow at 0^{o} to $40^{o}F$	Physiological	Personal load of rifleman be reduced to 28.2 pounds; personal load of BAR man be reduced to 34.0 pounds.	61

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Marching	Ammunition bags for crew-served weapons Weight not specified	Not specified	(Field) Tests of ammunition bag utilization conducted on hills with rocky and rough surfaces; and on low, rolling, sparsely vegetated sand dunes	Not specified	Ammunition bags should be replaced by Universal Load Carrying Strap. (See under LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	53
Crawling Falling and Getting Up Marching Running	Experimental ammunition pouch* Weight not specified	Carried alternately from belt and from "D" ring on suspenders	(Field) Marched 6-mile course under simulated combat conditions	Subjective preference	Experimental ammunition pouch preferred when carried in bandoleers in the pouch. Experimental pouch suitable replacement for cartridge belt and grenade pouch.	52
	Ammunition pouches with hand grenades Weight: T53-8 System - 12 lbs. Weight: UK Z. 2 System - 12 lbs.	Packs carried on back; pouches part of pack system	(Laboratory) Marched on level treadmill at 2. 5, 3. 5, and 5. 0 mph	Physiological	Pouches of T53-8 pack frequently cause pain by pounding on lower abdomen and upper thigh.	7

* Note: Operational status presently unknown

Equipment LOAD-CARRYING DEVICES: AMMUNITION POUCHES (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Climbing Creeping Falling and Getting Up Jumping Marching Rolling Running	Ammunition pouches carried: on T53-8 pack, on UK Z. 2 pack Weight of pouches on pack systems: not specified	Packs carried on back; pouches attached to pack system just above thighs on anterior surface of subject	(Field) Carried packs and engaged in activities specified	Physiological Subjective ratings based on comfort and interference of movements Performance time	Subjects complain of discomfort and interference caused by two ammunition pouches of T53-8 and UK Z. 2 pack. No increase in oxygen consumption or decrease in movements were discernible.	11
Agility and Balance Changing Direction Climbing Creeping Falling and Getting up Jumping Marching Rolling Running Throwing	Ammunition pouches carried: on T53-8 pack, on UK Z. 2 pack Weight of pouches on pack systems: not specified	Pouches located anterior surface of subject just above thighs	(Field) Carried packs and engaged in activities specified	Reaction time Performance time	Ammunition pouches interfere with movements which require flexion of the legs at hip joint. Performance of activities such as jumping, creeping, falling, and Burpee test for agility not adversely affected by position of ammunition pouches on T53-8 and UK Z. 2 pack systems.	17

Equipment: LOAD-CARRYING DEVICES: BAMBOO POLE

TASK/ACTIVITY	EQUIPMENT/LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	14-foot bamboo pole with 45-lb. load at one end Weight: 45 lbs. Weight of pole: not specified	Carried on shoulder	(Laboratory) Marched at 3-1/2 mph on level treadmill 1/2 hour daily for 8 days	Physiological	Poor performance with pole. Severe stress and pain of shoulder noted by subjects using pole.	59

Equipment LOAD-CARRYING DEVICES: CHEST CARRY

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	15-45 pounds carried around neck in a life preserver belt. Weight: 15-45 pounds	Carried load around neck balanced fore and aft	(Laboratory) Marched 3-1/2 mph on horizontal treadmill 1/2 hour daily for 8 days	Physiological	Loads balanced fore and aft on thoracic region better tolerated than anticipated.	59

Equipment LOAD-CARRYING DEVICES: JERKINS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a rifle Loading-unloading Bren Magazines Marching Shovelling sand	Assault Jerkin Weight: 4 pounds 8 oz. Weight of total load in Battle Order: 50 pounds 1 oz.	Worn around body	(Field and Laboratory) 3, 6, and 28 hour marches Simulated combat experiences Marched on treadmill for 1/2 hour at 3 mph	Physiological Rifle accuracy Time to fill Bren magazines Time to shovel sand Subjective ratings: Warmth Sweatiness Fatigue Chafing Body aches Equipment fit Equipment balance Foot comfort Photographic stills Water uptake & drying times Distribution of loads carried in Battle Order Environmental measures	None of equipment under trial occasioned physiological stress. Jerkin more adapted for 28-hour march than other equipment.	38

Equipment LOAD-CARRYING DEVICES: JERKINS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Donning and doffing Jerkin Loading a rifle Marching Obstacle course Producing: Water bottle Grenades Bayonet Bren Magazine Running and climbing Running down hill Running, jumping and climbing	Weight of unloaded Battle Jerkin: 3 pounds 8 oz. Weight loaded: not specified	Worn around body	(Field) Subjects wearing Battle Jerkin equipment engaged in various performance tests and field activities over three-week period	Physiological Questionnaires Performance data	Jerkin interferes less with general comfort and performance than does UK Z. 2 equipment. Bren Magazine pouches too small for present use. Jerkin cooler and more comfortable than UK Z. 2 equipment. Jerkin preferred for range firing. Jerkin has better all-round performance than UK Z. 2 equipment.	13

Equipment: LOAD-CARRYING DEVICES: KOREAN A-FRAME

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Various loads carried by A-frame Weight: not specified	Carried on back	(Field) Not specified	Evaluation of photographic studies	A-frame appears to: a) Protect back from hard or irregular loads due to its rigid structure. b) Minimize load motion c) Transmit weight of load through bony structures of the pelvis and hips. d) Apply less pressure to top of shoulder than does standard packboard.	6

Equipment LOAD-CARRYING DEVICES: PACKBOARD

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Army 5-gallon water cans filled with lead shot and strapped to plywood packboard Weight: 20-70 pounds	Carried on back	(Laboratory) Marched with pack on treadmill at 2.8 mph; horizontal, uphill, downhill	Pressure exerted by straps on: a) top of shoulder b) clavicle c) front of shoulder	Strap pressure greater at top than at front of shoulder when subject is standing. During walking, pressure increases. Larger the chest of subject, greater the pressure on shoulder front and smaller the pressure on shoulder top.	26
Marching	Same as above except weight: 20-80 pounds	Carried on back	(Laboratory) Marched with pack on treadmill at 2.8 mph; horizontal, uphill, downhill	Inclination of trunk of body as determined by photographic stills	Low pack causes greater trunk inclination than higher pack. Greatest trunk inclination occurred during standing or walking upgrade, least during standing or walking on horizontal or downgrade plane.	16
Marching	Packboard frame: 6-1/4 pounds *6 Standard blocks: 18-1/4 pounds (Total weight: 24-1/2 pounds) *Loads consisted of weighted wooden blocks.	Carried on back	(Laboratory) Marched with pack on treadmill at 2.5, 3.5, and 5.0 mph	Stroboscopic analysis of pack motion	Packboard with low distribution of weighted wooden blocks has extensive side sway.	7

Equipment: LOAD-CARRYING DEVICES: PACKBOARD (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Army 5-gallon water cans weighted with sand and mounted on plywood packboard Weight: 25-40 pounds	Carried on back	(Field) Marched 1-1/4 miles at 2.5 mph over desert terrain (Level sand, level hard surface, up sand dunes, down sand dunes)	Physiological	40-pound pack carried at 2.5 mph continuously for 1/2 hour appears to represent extreme upper load limit for any sandy area in the desert. Pulse rates and rectal temperatures increase while marching over sand and slope areas.	8
Marching	Packboard Weight: 35-pound total load Type of load: not specified	Carried on back	(Field) Marched 18 miles over straight and level terrain and over hills, sand, brush and trees	Preference	Packboard rates second to field pack	52
Marching	Packboard Weight: 55-pound total load Type of load: not specified Packboards ranged in size from 20"x12" to 24"x15" (standard)	Carried on back	(Field) Marched seven miles, wearing different size packboard for one mile	Preference	20"x12" packboard and 20"x13" packboard disliked by all subjects. Narrow packboards as good as standard but no better.	52

Equipment LOAD-CARRYING DEVICES: PACKBOARD (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Packboard Weight: 55-pound total load Type of load: not specified Packboard: 24"x 12" w/attachment for carrying small pack and bedroll	Carried on back	(Field) Marched 55 miles over straight and level terrain, and cross-country (hills, sand, brush and trees)	Performance ratings Utility ratings	Packboard adds unnecessary weight: too much weight on shoulder. Difficult to carry rifle when wearing packboard	52
Marching	Plywood pack-board Weight: 40-pound total load	Carried on back	(Laboratory) Subjects marched on level treadmill at 2.8 mph	Pressure exerted by straps on a) top of shoulder b) clavicle c) front of shoulder	Total pressure exerted by straps of packboard greater than that of Standard Field pack, Rucksack, UK 1.2 pack, or US T53-8 pack.	12
Marching	Plywood pack-board Weight: 27-78 pounds	Carried on back, high and low on pack-board	(Laboratory) Subjects marched on treadmill at 3.5 mph	Physiological	Slight advantage in carrying weights of 46 pounds high on pack-board and heavier weights low on packboard.	57
Marching	Plywood pack-board Weight: 45-pound total load	Carried on back, high and low on pack-board	(Laboratory) Marched at 3.5 mph on horizontal treadmill 1/2 hr. a day for 8 days	Physiological	Packboard acceptable way of carrying loads up to 45 pounds.	59

Equipment LOAD-CARRYING DEVICES: PACKBOARD (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Transporting electronic equipment Marching	Electronic equipment units mounted on packboard Weight: 39-66 pounds Weight of packboard: Not specified	Carried on back	(Field) Marched over varying terrains	Time to transport equipment	Some loads too heavy, require division into smaller units. Some loads inhibit freedom of both hands and flexibility of movement. All weight of one unit placed on one side of carrier and requires hand to balance load. Carbine unable to be carried in usable position. Package unable to be drawn tightly to carrier's body due to shoulder strap arrangement. Equipment juts out from packboard frame.	39

Equipment LOAD-CARRYING DEVICES: PACKS, MISCELLANEOUS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Climbing Creeping Descending Falling and Getting Up Jumping Marching Rolling Running	U.S. Standard Pack* Weight: 27 pounds total load	Carried on back	(Field) Engaged in activities as specified	Physiological Subjective rating based on comfort and interference of movements Performance time	According to subjective ratings, U.S. Standard Pack best when compared with T53-8 and UK Z. 2 packs. On basis of physiological measures (energy cost) and performance time, U.S. Standard Pack not superior to T53-8 or UK Z. 2 pack. Except for climbing, falling and getting up, and descending, performance was faster without a pack than with a pack. With load high on the back, load bounces up and down and sideways during all tests except creeping and climbing.	11

* Note: Operational status unknown

Equipment LOAD-CARRYING DEVICES: PACKS, MISCELLANEOUS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Agility Balance Changing direction Climbing Creeping Falling and Getting Up Jumping Marching Rolling Running Throwing	U.S. Standard Pack* Weight: 27 pounds total load	Carried on back	(Field) Carried pack on back and engaged in activities specified	Performance time Reaction time	Creeping performed as rapidly with a pack as without pack. Falling performed as rapidly with pack as without pack. Grenade throwing less accurate with U.S. Standard Pack than with T 53-8 or UK Z. 2 packs.	17
Marching under load	Standard Combat Pack* Weight: 25 pounds total load *Note; Operational status unknown.	Carried on back	(Laboratory) Marched on treadmill at 2.5, 3.5, and 5.0 mph	Physiological	Standard combat pack as efficient as T53-8 pack, UK Z.2 Pack and packboard at 2.5 and 3.5 mph. Movement of standard combat pack frequently out of phase with motion of the body.	
Marching	Framed carriers Weight: not specified	Carried on back	Not specified	Not specified	For combat purposes, uppermost pack is detached by release of straps. Weight of complete equipment excessive. Frame has to be carried in combat.	27

Equipment LOAD-CARRYING DEVICES: PACKS, MISCELLANEOUS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Frameless carriers	Carried on back	Not specified	Not specified	Weight decreased by omission of frame. Storage space, both empty and filled, is minimal. Weight of pack borne on shoulders causing fatigue and discomfort to shoulder muscles.	27
Marching	Manpack carrier* Weight: 20-50 pounds	Carried on back	(Field) Marched 5-7 miles at 3.6 mph in Northern Punjab at 35°F to 65°F on dry days with little to no wind	Harvard Step Test Fatigue	For a march of 5 miles at 3.6 mph, with weight of 20-50 lbs., following relationship holds: Efficiency = 91 - 3/4 of load carried. Percentage Fatigue = 25 - 7/8 load carried. Fighting soldier should not carry more than 43 pounds inclusive of the Manpack carrier. Loads of 65 pounds may be excessive for porters.	32

* Note: Operational status unknown.

Equipment LOAD-CARRYING DEVICES, PACKS, MISCELLANEOUS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Pack, field, combat and cargo M1945, * consisting of: a) Pack, field combat b) Pack, field cargo c) Suspenders Weight: 58-112 pounds	Carried on back and worn	(Field) Not specified	Load analysis Preference	M 1945 pack preferred by majority of troops. Method of attaching pack components too complicated. Buckles difficult to fasten and unfasten. Suspender attachments act as stabilizing agent for load, prevent shifting of load downward during carrying.	50
Marching	Jacket, Field, M 1943 (Modified) *Experimental with back pouch, consisting of three integral units: a) Jacket with back pouch b) Inner carrying compartment c) Suspenders Weight: not specified	Carried on back and worn	(Field) Not specified	Preference Load analysis	Affords more inner space when summer uniform is worn.	50

* Note: Operational status unknown.

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Field Pack*	Carried on back	(Field) 6-mile march over straight, level terrain, and hills, sand, brush and trees	Preference	Distributes weight better than packboard or Rucksack.	52
Marching	Experimental combat pack* Weight: 46 pounds carried under simulated non-combat conditions Weight: 37 pounds carried under simulated combat conditions	Carried from suspenders or belt	(Field) 55-mile march under simulated combat conditions over straight, level, and cross-country (hills, marsh) terrain	Preference Ratings of performance and utility	Easy to put on - off; enough space for minimal existence items.	52
Marching	Experimental low back pack w/ straps for carrying horseshoe roll* Weight: same as above	Carried low on back (sacral region)	(Field) Marched 55 miles under simulated combat and non-combat conditions over varying terrains	Preference Ratings of performance and utility	Disliked for use when running and crawling, falls away from body at top, results in unbalanced load.	52
Marching	Experimental pack w/integral shoulder straps, and straps for carrying horseshoe roll* Weight: same as above	Carried on back	(Field) Marched 55 miles under simulated combat and non-combat conditions over varying terrains	Preference Ratings of performance and utility	Preferred, but inferior to Experimental combat pack (see above).	52

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Modified field jacket w/attachments for carrying poncho, rations, and other necessary items* Weight: same as above	Carried on back and worn	(Field) Marched 55 miles under simulated combat and non-combat conditions over varying terrains	Preference Ratings of performance and utility	Universally disliked. Not possible to drop load without dropping entire jacket. When unbuttoned, doesn't carry well.	52
Marching	Standard field pack*	Carried on back	(Field) Marched 55 miles under simulated combat and non-combat conditions over varying terrains	Preference Ratings of performance and utility	Universally disliked. Hard to adjust because of too many straps and buckles.	52

* Operational status unknown.

Equipment LOAD-CARRYING DEVICES: RUCKSACKS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Bergen type rucksack	Carried on back	----	----	Weight of load in rucksack carried partly on hips and partly on shoulders. Load center of gravity too far to rear of body center of gravity, leads to fatigue. Storage space in rucksack excessive. Curved metal frame awkward.	27
Firing a rifle Loading-unloading Bren Magazines Marching Shovelling sand	Bergen type rucksack Weight: 52 pounds 5 oz. total load	Carried on back	(Field and Laboratory) 3, 6, and 28 hour marches Simulated combat conditions Marched on treadmill for 1/2 hour at 3 mph	Physiological Rifle accuracy Time to fill Bren Magazines Time to shovel sand Subjective ratings Photographic stills Water uptake and drying times	With change of speed and direction, rucksack wobbles during marching, causing discomfort and waste of body energy. Rucksack chafes skin. Rucksack upsets body balance. Rucksack worn, when in prone position, prevents effective rifle firing.	38

Equipment LOAD-CARRYING DEVICES: [illegible]

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
				Distribution of loads carried in Battle Order. Environmental		
Marching	Rucksack Weight of total load: 35 pounds	Carried on back	(Field) Marched 18 miles over straight and level terrain, and over hills, sand, brush and trees	Preference	Rucksack rated third to field pack. In rucksack, weight carried low on back. Rucksack possibly useful under mountain or arctic conditions.	

Equipment LOAD-CARRYING DEVICES: SLEDS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Pulling a sled	Sled Weight total load: 75-218 pounds	Pulled	(Field) Pulled sled over level snow at 0^{o} to 40^{o}F	Physiological	Energy expenditure per unit distance depends mainly on drag and not on walking pace. Pulse rate rises with increase in drag at a slow walking rate; climbs sharply as speed increases. Softness and depth of snow result in greater physiological strain than frictional elements due to low snow temperature or grain form. Payload of 125 pounds(at 15 pounds pull)at speed of 2 mph is optimum compromise between work accomplished and physiological strain in sled pulling by one man over level snow.	61
Pulling a sled	Sled Weight total load: 17-45 pounds	Harness used encircled shoulders and waist of subject	(Field) Engaged in load haulage under varying load conditions, wearing different clothing ensembles	Physiological	Sled pulling is hard work, from physiological viewpoint. Small posterior pull causes marked increase in energy cost.	60

Equipment LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Universal load-carrying straps Weight: not specified	Used in various positions	(Field) Marched over hills with rocky and rough surfaces Marched over low, rolling, sparsely vege-tated sand dunes	Not specified	Universal load-carrying strap will carry quantities of ammunition equal to and, in most cases, greater than standard ammunition bags. (See also under LOAD-CARRYING DEVICES: AMMUNITION POUCHES)	53
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds With; Improved Loop Sling Combat Rifle Sling No sling Weight of slings: not specified	Rifles supported by sling and arms with operator in prone position	(Field) Fired .30 caliber M2 ball ammunition at ranges of 200-300 yards	Preference Accuracy	Use of sling results in increased marksmanship during training. Present Improved Loop Sling not suitable for Army use. Same accuracy of fire with combat rifle sling as with Improved Loop Sling. Firing with a Combat Sling is as fast as firing without a sling. Combat sling preferred to Loop Sling. (See also under RIFLES)	18

Equipment LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Various loads carried by Korean A-Frame Weight: not specified	Carried on back	(Field) Not specified	Evaluation of photographic stills	Mounting of straps on A-frame obviates interference with shoulder motion. Low insertion of straps reduces restriction to shoulder motion and likelihood of pressure on vascular and nervous structures. Wide separation between origin and insertion of carrying straps allows ease of getting into load or of jettisoning it in case of emergency. (See also under LOAD-CARRYING DEVICES: PACKBOARD AND U.S. EXPERIMENTAL PACK T53-8)	6
Operating a hand-held radar	Mockup of AN/PPS-6 lightweight hand-held radar with neck support Weight of mock-up: 5 pounds Weight of neck support strap: not specified	Suspended via strap from subject's neck	(Laboratory) Simulated operation of radar	Steadiness	Neck strap support preferable to hand-held mode, even when elbow is supported. (See also under PISTOLS AND RADARS, HAND-HELD)	9

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a grenade launcher	Ammunition carrier for 40 mm grenade launcher M79	Many and varied as under conditions of actual combat	(Field) Simulated combat conditions	Equipment evaluation	Elastic loop carrier required to carry M79 ammo rounds across the body. Present 27 pound load too heavy to be carried in prescribed manner.	54
Firing a rifle	Rifle used with sling Weight of rifle; not specified Weight of sling; not specified	Worn tightly around upper forearm	(Field) Engaged in rifle marksmanship training	Medical procedures	Of 1213 Marine Corps recruits, 97 revealed some arm nerve deficit; 8 showed sufficient disability to interfere with performance of duty. All but two recovered in three weeks. (See also under LOAD-CARRYING DEVICES: PACKBOARDS)	3
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds with: Hasty sling Loop sling No sling Weight of slings: not specified	Rifle supported by sling and arms with operator in prone position	(Field) Fired .30 caliber ball ammunition at Type A Army targets 200 yards away	Accuracy	Loop sling superior to hasty sling condition and to no-sling condition. Marksmanship generally better with loop sling than with hasty sling or no sling. No sling and hasty sling equally effective. (See also under RIFLES)	44

Equipment LOAD-CARRYING DEVICES: SWISS COMBAT CLOTHING *

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching (Other field activities not specified)	Ensemble including: Jacket with attached hood and face camouflage Weight: 5 pounds 5 oz. Trousers with attached suspenders Weight: 3 pounds 10 oz. Rucksack Weight: 11 pounds 4 oz. Total weight: 20 pounds 3 oz.	Worn on body	(Field) Many and varied (Exact conditions not specified)	Total load Weight distribution Stability Breathing, blood circulation, and shoulder pressure Time required to change from field load to combat load Ease of maneuver Adaptability to different climates Sweating Camouflage	Load carried in jacket suspends from yoke of jacket. Jacket doesn't balance well on shoulders under load. Wearer subject to physical stresses which accompany low pack. Load carried in jacket relatively instable while soldier is in motion; pack tends to sway and swing while in motion.	46

* Note: Operational status unknown

Equipment LOAD-CARRYING DEVICES: THIGH CARRY

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	15 pounds distributed equally in each of two mid-thigh cargo pockets	Carried in mid-thigh cargo pockets	(Laboratory) Marched at 3-1/2 mph on horizontal treadmill 1/2 hour daily for 8 days	Physiological	Load carrying of 15 pounds on thigh leads to energy expenditure equivalent to carrying 45 pounds on back. Thigh carry is inefficient and fatiguing method.	59
(Other field activities not specified)	Swiss Combat Clothing Ensemble with integrated load-carrying equipment Weight: not specified	(See under LOAD-CARRYING DEVICES: SWISS COMBAT...)	(See under LOAD-CARRYING DEVICES: SWISS COMBAT...)	(See under LOAD-CARRYING DEVICES: SWISS COMBAT...)	Cargo pockets in trousers are a hindrance.	46

Equipment LOAD-CARRYING DEVICES: UNITED KINGDOM Z. 2 PACKS*

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Agility Balance Changing direction Climbing Creeping Falling and Getting Up Jumping Marching Rolling Running	United Kingdom Z. 2 pack system* Weight total load: 27 pounds	Carried on back	(Field) Carried pack and engaged in activities as specified	Reaction time Performance time	Grenade throwing not as accurate with UK Z 2 pack as with U.S. Standard Pack or U.S. T53-8 Pack	17
Firing rifle Loading-unloading Bren Magazines Marching Shovelling sand	United Kingdom Z. 2 pack system* Weight total load: 52 pounds 1 oz.	Carried on back	(Field and Laboratory) 3, 6, and 28 hour marches Marched on treadmill 1/2 hour at 3 mph	Physiological Performance tests Subjective ratings Distribution of loads carried in Battle Order Water uptake and drying times Photographs Environmental	UK Z. 2 does not cause physiological strain as measured objectively or subjectively. UK Z. 2 equipment suitable for gruelling marches. UK Z. 2 equipment generally superior to assault Jerkin and Bergen Rucksack. UK Z. 2 equipment clings to body, resulting in increased stability.	38

* Note: Believed to be no longer operational.

Equipment LOAD-CARRYING DEVICES: UNITED KINGDOM Z. 2 PACK (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Doffing and donning Loading 10 rounds of ammunition into rifle Marching Obstacle course Producing: Water bottle Grenades Bayonet Bren Magazine Running and climbing Running downhill Running, jumping and climbing	United Kingdom Z. 2 Pack Weight: not specified	Worn around body	(Field) Subjects wearing UK Z. 2 load-carrying system and Battle Jerkin engaged in various performance tests and field activities over three-week period	Physiological Questionnaires Performance data	UK Z. 2 load-carrying system better for doffing and donning than Battle Jerkin. No differences in producing items (ease of access) between UK Z. 2 system and Battle Jerkin. In short activities, UK Z. 2 system interferes significantly more in running, jumping, crawling, and rolling; bounces about more than Battle Jerkin.	13
Marching	United Kingdom Z. 2 load-carrying system Weight of pack: 5-1/2 pounds Weight total load: 25 pounds	Carried on back	(Laboratory) Marched on treadmill at 2. 5, 3. 5, and 5. 0 mph	Physiological	UK Z. 2 pack as efficient as the T53-8 pack, Standard Combat Pack, or Packboard when marching at 2. 5 and 3. 5 mph.	7

Equipment LOAD-CARRYING DEVICES: UNITED KINGDOM Z. 2 PACK (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Climbing Creeping Falling and Getting Up Jumping Marching Rolling Running	United Kingdom Z. 2 load-carrying system Weight total load: 27 pounds	Carried on back	(Field) Carried pack on back and engaged in specified activities	Physiological Subjective ratings based on comfort and interference of movements Performance time	Less energy expended when activities performed without a pack than with a pack. According to subjective rating, UK Z. 2 rates third to T53-8 pack and U. S. Standard Pack. UK Z. 2 Pack not superior to T53-8 Pack or U. S. Standard Pack on basis of physiological measures.	11
Marching	United Kingdom Z. 2 load-carrying system Weight total load: 40 pounds	Carried on back	(Laboratory) Marched on treadmill at 2. 8 mph	Pressure exerted by straps at: top of shoulder front of shoulder	When compared to pack straps of U. S. Standard Field Pack, the Rucksack, T53-8 Pack, or the Packboard, the straps of United Kingdom Z. 2 Pack apply lowest pressure on top of shoulder. (See also under: LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	12

Equipment LOAD-CARRYING DEVICES: U.S. EXPERIMENTAL PACK T53-8*

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Agility Balance Changing direction Climbing Creeping Falling and Getting up Jumping Marching Rolling Running Throwing hand grenades	T53-8 Experimental Pack Weight total load: 27 pounds	Carried on back	(Field) Carried load-carriage system and engaged in activities specified	Reaction time Performance time	Throwing grenades as accurate while carrying T53-8 system as without any load-carriage system. Falling (hitting the dirt) performed as rapidly while carrying T53-8 pack as without a pack. Balance maintained equally well with T53-8 pack as without a pack. No difference in reaction time with or without a pack.	17
Falling Marching Obstacle course Running stairs	T53-8 Experimental Pack Weight total load: 25 pounds	Carried on back	(Laboratory) Marched on treadmill at 2.5, 3.5, and 5.0 mph	Physiological Time to run obstacle course	At speed of 5 mph, T53-8 is better load-carrying system than packs with high back locations. Men run faster with T53-8 standard combat pack than with Standard Combat Pack, UK Z.2 Pack, or Packboard. Location of T53-8 Center of gravity permits easier falling.	7

*Note: T53-8 system with modifications now operational as M56 load-carrying system.

Equipment LOAD-CARRYING DEVICES: U.S. EXPERIMENTAL PACK T53-8 (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
					T-53-8 more stable in anterior-posterior line than Standard Combat Pack. "Shucking" up and down of T53-8 system largely in the vertical plane. T53-8 pack more stable when running than standard high position combat load.	7
Climbing Creeping Falling and Getting Up Jumping Marching Rolling Running	T53-8 load-carrying system Weight total load: 27 pounds	Carried on back	(Field) Engaged in specified activities four times for each test	Physiological Subjective ratings based on comfort and interference of movements Performance time	T53-8 Pack rates 2nd best to U.S. Standard Pack. T53-8 not superior to U.S. Standard Pack or UK Z.2 on basis of energy cost and performance time. Less energy expended when activities performed without a pack than with a pack.	11
Marching	T53-8 load-carrying system Weight total load: 40 pounds	Carried on back	(Laboratory) Marched on treadmill at 2.8 mph	Pressure exerted by pack straps on: top of shoulder, front of shoulder	When compared to pack straps of U.S. Standard Field Pack, the Rucksack, the UK Z.2 Pack, and the Packboard, the straps of T53-8 apply lowest pressure on front of shoulders	12

Equipment LOAD-CARRYING DEVICES: U.S. Experimental Pack T53-8 (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
					T 53-8 lowest strap pressure per unit area for four packs measured. (See also under: LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	12

Equipment LOAD-CARRYING DEVICES: VESTS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Vest, combat and cargo weight: 10 oz. Vest, combat and cargo Weight: 7.9 oz. Weight total loads carried:58-112 pounds	Worn around body	(Field) Not specified	Best method for load transport	Weight of equipment carried within and on front of vest, 10-oz. component insufficient to stabilize rear load. Weight of vests causes excessive perspiration, less so for 7 oz. than 10 oz.	50

Equipment LOAD-CARRYING DEVICES: WAIST CARRY

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	"Saddle-bag" style around the waist Weight: 15-45 pounds	Carried around waist	(Field) Marched on treadmill at 3.5 mph daily for 8 days for 1/2 hour	Physiological	Carrying loads around waist as favorable as carrying loads on packboard (on back).	59
Marching	"Saddle-bags" four on each side Weight total load: 27-78 pounds	Carried around waist	(Laboratory) Marched on treadmill at 3.5 mph	Physiological	Waist suspension of loads not superior to carrying loads on back.	57

Equipment LOAD-CARRYING DEVICES: WHEELED CARTS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Transporting electronic equipment	Electronic equipment unit	Pulled by two men in a two-wheeled tow cart	(Field) Two-wheeled cart used to carry electronic equipment cross-country, up slopes, and in snow and mud	Time to transport equipment	Adds 10-15 minutes to transport time and leaves men in fatigued condition.	39

Equipment MACHINEGUN

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a machinegun	Machinegun 7.62 mm, M60 Weight unloaded: 23 pounds	Many and varied as found under conditions of actual combat	(Field) Simulated combat conditions	Hits per target Ammunition expenditure Tactics evaluation Mission evaluation	More than one man required to effectively service and operate weapon. M60 in automatic rifle role restricts mobility and maneuverability of rifle squad. M60 ammunition belt causes many gun stoppages. Target hit patterns of M60 show definite advantage at greater ranges.	54

Equipment MORTARS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Mortar portage	T-201 Mortar Weight: 100-170 pounds	Carried by stretcher-type and satchel-type handles	(Field) Marched on flat open ground; climbed slopes, walked along hillside; hiked in wooded areas, and over obstructions	Distance Rate of carry time Frequency of rest	Stretcher-type handles improve portability	5
Mortar portage	T-201 Mortar Weight: 367 pounds M 30 Mortar Weight: 650 pounds	Carried by bi-pod and over shoulders; carrying mortar in the hand	(Field) Mortar crews ran through series of tests simulating firing missions	Portability Time and motion	Time for carrying both mortars is the same.	55
Setting up mortar	T-201 Mortar Weight: 367 pounds M 30 Mortar Weight: 650 pounds	----	(Field) Ran through series of tests simulating firing missions	Small and gross changes Sequence firing Time and motion Emplacement and Displacement	M 30 takes more than 3 times normal emplacement time to set up; T 201 requires less than 1-1/2 times as long. Time to relay weapon greatly reduces rate of fire. Leaving sight on mortar during firing and using 2-man operation should provide fastest firing time.	55

Equipment MORTARS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Loading a Mortar	X mm Mortar* Weight: 40 pounds	Lifted mortar overhead and placed into mortar by operator in standing position	(Laboratory) Simulated mortar loading conditions	Loading time	Shell 40" long and weighing 40 pounds capable of being loaded under most conditions by most men. For loading shells, at 70° elevation as used in this study, lower limit of heights required for operators approximately 5'5". (See also under CONTAINERS AMMUNITION)	56

*Note: Exact name of mortar classified.

Equipment PISTOLS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a pistol	Pistol, automatic Cal. 45 Weight unloaded: 2-1/2 pounds	Pistol held in hand when firing; first held with one hand, then held with both hands.	(Field) Fired at Standard Army silhouette 25 yards away	Number of targets hit	Use of two-handed grip results in greater mean number of hits made. More perfect scores made by users of two-handed grip.	47
Firing a pistol	Mock-up of AN/ PPS-6 Lightweight Hand-Held Radar Weight: 15.3 pounds Mock-up Weight: 5 pounds	Mock-up held in favored hand with arm fully extended in front of body	(Laboratory) Simulated operation of radar	Steadiness	Pistol grip method of support not to be used unless weight less than 5 pounds.	9

Equipment RADAR, HAND-HELD

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Operating hand-held radar	Mock-up of AN/ PPS-6 Light-weight Hand-held Radar Mock-up weight: 5 pounds	Supported with pistol grip Supported from neck Steadied by holding elbow of arm supporting radar set	(Laboratory) Simulated operation of radar	Steadiness Endurance time	Pistol grip method of support not to be used unless weight is less than 5 pounds. Marked improvement in steadiness with a more comfortable method of support. Neck strap support preferred to hand-held method, even when elbow is supported. (See also under PISTOLS and under LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	9

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a rifle	U.S. Rifle Cal. 30, M1 Weight unloaded: 9-1/2 pounds	Supported by subject in standard firing position	(Field)	Marksmanship after issuance of fitted rifle stock	Personalized rifle stocks ineffective in significantly improving rifle marksmanship.	35
Firing a rifle	U.S. Rifle Cal. 30, M1	Supported by subject using Improved Loop Sling, Combat Sling, and no sling	(Field) Fired M2 ball ammunition at ranges of 200 and 300 yards after dropping to prone firing position	Accuracy Speed	Use of sling during training results in increased accuracy (For further information, see under LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	18
Firing a rifle	U.S. Rifle, Cal. 30, M1 with cant measuring device attached to bayonet stand Weight of unloaded rifle: 9-1/2 pounds; weight of cant measuring device: not specified	Fired from standing and sitting position	(Field) Simulated firing at regulation SB-D (bullseye) and SB-A (prone) targets 100 yards away	Cant (for definition of Cant, see under RIFLES, RECOILLESS)	Firing rates and targets exert only minor influence on cant with the M1. Individual gunner and his firing position are major factors in use of this weapon.	49
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds	Supported by subject in prone position with: no sling hasty sling, loop sling	(Field) Fired M2 ball ammunition at Type A Army targets at a distance of 200 yards	Accuracy	Loop sling superior to hasty sling and no sling conditions. For further information, see under LOAD-CARRYING DEVICES: SLINGS, BANDOLEERS)	44

Equipment RIFLES (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Firing a rifle	U.S. Rifle, Cal. 30, M1 Modified to weigh as follows: 9.8 pounds 10.00 pounds 10.25 pounds 11.81 pounds 12.00 pounds 12.25 pounds 13.8 pounds 14.00 pounds 14.25 pounds	Weighted rifles supported by subject in prone position	(Field) Fired at Type A Army Targets 200 yards away	Accuracy	No significant difference in accuracy attributable to rifle weight. Shooters behaviorally "insensitive" to the range of weapon weights and resultant recoil energies obtained.	42
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds Modified U.S. Rifle, Cal. 30, M1 Weight not specified	Rifle resting on sandbag	(Field) Modified rifle comb per individual preference and then sighted and fired on Type A Army targets 200 yards away	Accuracy	No significant difference in shooting performance attributed to differences in comb conditions. No significant relationship between facial measurements of subjects and selected comb location.	25
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds	Supported by subject in prone position with loop sling	(Field) Fired at Type A Army targets 200 yards away while wearing Type V-51R ear plugs	Accuracy	No significant difference in shooting performance attributable to use of ear plugs.	3

Equipment RIFLES (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a rifle	U.S. Rifle, Cal. 30, M1 with: four different types of cartridges used to produce different levels of recoil Weight unloaded: 9-1/2 pounds	Rifle resting on sandbags used with and without slings	(Field) Fired at Type A Army targets 200 yards away	Accuracy Medical examination Subjective report form Frequency with which subjects voluntarily terminated firing	Upper limit of rifle recoil for moderately proficient marksmen is 19.3 foot-pounds of free recoil energy. Arm-shoulder movement not limited, nor strength impaired by firing; however, shoulder area uncomfortable during shooting. Recoil causes redness and swelling of shoulder area. Hearing loss resulted due to rifle firing. Recoil believed to affect marksmanship. Subjects using ammunition causing highest level of recoil when fired from M1 terminated rifle firing more frequently than subjects in other groups. Variations in rifle recoil between 11.0 and 25.5 foot-pounds, lead to observable differences in tissue damage, subjective discomfort, unwillingness to continue firing and over-all marksmanship performance.	41

Equipment RIFLES (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
					Minimal to good shooters have degraded marksmanship performance when rifle recoil exceeds 19.3 foot-pounds. For expert or superior shooters, rifle recoil may exceed 25.5 foot-pounds of free recoil energy. Precision most systematically affected by variations in rifle recoil. Marksmanship performance not due to number of rounds fired, or number of days of firing.	41
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds	Supported by standing operator	(Field and Laboratory) Engaged in physical activities under conditions of hot and cold stress before and after: Rifle Aiming Steadiness Test, Serial Reaction Test	Tremor errors made Time to perform task Total number of taps made	Short duration activity (push-ups) results in significant increase in horizontal tremor. Marching in low temperature results in increased tremor. Heat stress and exercise has no apparent effect on rifle aiming steadiness.	34

Equipment RIFLES (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
					Serial reaction time and errors not affected by hot-cold stress.	34
Firing a rifle	U.S. Rifle, Cal. 30, M1 Weight unloaded: 9-1/2 pounds	----	-----	Preference	M1 rifle not preferred over experimental rifles. M1 rifle easier for performance of manual arms.	31

Equipment RIFLES, AUTOMATIC

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Firing an automatic rifle	U.S. Rifle, 7.62 mm, M14 Weight unloaded: 9.7 pounds	Supported while operator fired from prone and hip positions	(Field) Simulated combat conditions	Hits per target Ammunition expenditure Tactics evaluation Mission evaluation	M14 (M) overheats after firing less than 100 rounds at full automatic rate. High cyclic rate of M14 (M), coupled with instability causes gunner to become gun shy. Stability of M14(M) marginal when fired from prone position. M14 (M) gunners, firing from hip and shoulder, experience difficulty in holding weapon on target. Present M14(M) not suitable replacement for BAR.	54
Firing an automatic rifle	Browning Automatic Rifle, Cal. 30, M 1918A2 Weight unloaded: 19-1/2 pounds T-48 Rifle* T-48 E-1* Automatic Rifle			Preference	T-48 E-1 rates poorly on steadiness under full automatic fire, susceptibility to stoppage, and firing for record.	31

* Neither name nor weight of T-48 rifles are given in study.

Equipment RIFLES, RECOILLESS

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Firing a recoilless rifle	3.5" Rocket Launcher, M20 with cant measuring device mounted on the rear barrel Weight loaded: 22 pounds	Supported by operator in standing and sitting positions	(Field) Fired at 1/4-ton trucks 440-557 feet away	Cant*	Individual gunner's error and his response to target orientation major factors influencing cant in the M20 Orientation of target with respect to terrain and background exert strong influence on direction and magnitude of error. Cant exerts no noticeable effect on hit probability for first or subsequent rounds at ranges less than 600 feet and only slight effects at ranges up to 1200 feet with M28 and M36 Rockets.	49
Carrying a recoilless rifle	90 mm Rifle, M67 Weight loaded; 44 pounds	Many and varied as found under conditions of actual combat	(Field) Simulated combat conditions including Advance to Contact, Attack, Defensive phases	Mission evaluation Tactics evaluation Personnel load, size and weight	Recoilless rifle crew for M67, 90 mm unable to keep pace with remainder of rifle platoon; M67 rifle seriously restricts maneuver and movement of unit.	54

* Cant: Angular deviation from the vertical imparted to a weapon by the gunner or environment, and which may constitute a serious obstacle to the delivery of accurate fire.

Equipment RIFLES, RECOILLESS (Continued)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF
Firing a recoilless rifle	M72, Light Anti-tank Weapon, 66 mm Weight: 4.5 pounds complete system	Supported by operator in kneeling position, rifle held on shoulder	(Field) Simulated combat conditions including Advance to Contact, Attack, and Defensive phases	Hits per target	All gunners trained direct hits at ranges of 135-145 meters.	54

Equipment TOOL, INTRENCHING

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching Obstacle course Running stairs Falling and Getting Up	Intrenching tool combination Weight: 4-1/2 pounds Weight total load: 25 pounds	Intrenching tool and bayonet mounted on rear of pack	(Field and Laboratory) Marched on treadmill at 2.5, 3.5, and 5.0 mph Subjects ran obstacle course, "hit the dirt," and run up stairs	Physiological Time to run obstacle course Subjective Stroboscopic analysis of pack and component equipment motion	Intrenching tool on pack swings and bangs less than when fastened to wearer's belt.	7
Marching Running Jumping Falling and Getting Up Creeping Rolling Climbing	Intrenching tool Weight: not specified Weight total load: 27 pounds	Mounted on rear of pack	(Field) Engaged in activities specified	Physiological Performance time Subjective rating based on comfort and interference of movements	Intrenching tool bounces against head and neck frequently displacing helmet.	11

Equipment TRIPODS, BIPODS AND EQUIPMENT SUPPORTS (LEGS, STANDS, ETC.)

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Transporting Electronic Equipment Marching	Electronic Equipment Unit Weight: 39 pounds	Carried on back	(Field) Marched over varying terrains	Equipment evaluation	Equipment legs catch on brush and strike objects Tripod legs of equipment unit points toward carrier's back.	39
Firing a machinegun	Machinegun, 7.62 mm, M60 with tripod, and bipod Weight of MG:23 pounds (including shoulder stock and bipod) Weight of tripod: not specified	Mounted on bipod when used as an automatic rifle	(Field) Simulated combat conditions	Equipment evaluation Mission evaluation Tactical evaluation	M60 mounted on a tripod and used as a machinegun consistently outfires M60 mounted on a bipod. When moving through brush, bipod legs sometimes catches on underbrush and slows gunner's movements.	54
Setting up a mortar	T-201 Mortar Weight: 367 pounds	Supported on tripod	(Field) Ran through series of tests simulating firing missions	Portability Time and motion	Bipod most difficult section of T-201 mortar equipment to carry. Bipod handles too large. Center of gravity mainly at one end. Shape of mortar bipod handle makes it difficult to hold to center line of porter's body. Bearer of end of heavy bipod forced to take short steps, since bipod, because of shape, hits bearer about legs and groin as he takes average steps.	55

Equipment VESTS, ARMOR

TASK/ACTIVITY	EQUIPMENT/ LOAD	MODE	CONDITIONS	PERFORMANCE MEASURES	RESULTS	REF.
Marching	Armored vest, nylon, T52-1 Weight: 8 pounds Weight total loads carried: 25-45 pounds	Worn around body	(Field) Marched over course of 1.44 miles consisting of loose sand, semi-pavement, loose cobble-stones, and silt at average rate of 2.88 mph	Physiological	Energy expenditure increased as subjects march from hard surface to sandy areas.	11
Marching	Armored vest, Nylon, T52-1 Weight: 8 pounds Weight total pack load: 40 pounds Type of pack not specified	Worn around body	(Field and Laboratory) Marched on tread-mill on level course at 3.5 mph for 1/2 hr. twice daily for 5 con-secutive days. hiked up moun-tains with 3^{o}-22^{o} slopes	Physiological	Metabolic rate in-creases as steepness of slope increases.	58

APPENDIX C

PRIMARY REFERENCES

APPENDIX C

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APPENDIX D

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APPENDIX E

LIST OF INDIVIDUALS AND AGENCIES VISITED OR CORRESPONDED WITH

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LIST OF INDIVIDUALS AND AGENCIES VISITED OR CORRESPONDED WITH

This Appendix lists the agencies and individuals who contributed to the information presented in this report, either through personal interview and discussion, or through correspondence.

The following agencies and individuals were visited:

U.S. Army Research Office, Washington, D.C.

Major Thomas H. Tackaberry
Jacob L. Barber, Jr.

U.S. Army Special Warfare Center

Major Bue
Sgt. Chadwick
Sgt. Davis

U.S. Army Infantry Board

Col. W.M. Summers, President, USAIB
Col. R.C. Williams, Jr., Deputy President, USAIB
Col. Inman, USAIB
Lt. Col. Cougill, USAIB
Lt. Col. Price, USAIB
Lt. Col. Roberts, USAIB
Lt. Col. McClaren, USAIB (British Liaison Officer)
Major House, USAIB (Marine Corps Liaison Officer)

U.S. Army Infantry School

Lt. Col. Joseph, Combat Development Office, USAIS
Major Ondishko, Ranger Department, USAIS
Captain Bearss, Combat Development Office, USAIS

U.S. Army Infantry Human Research Unit

Dr. Thomas F. Nichols, USAIHRU
Col. H.E. Kelly, USAIHRU

U.S. Army Ordnance Human Engineering Laboratories

Dr. John Wiesz
Dr. Leon Katchmar
Bob Gschwind
John A. Stephens
Juri Torre

U.S. Army Quartermaster Research and Engineering Command

Dr. E. Ralph Dusek
Dr. Russell Newman
Dr. Jack M. Planalp
Mr. John Slaughta

Inquiry or correspondence was directed to the following organizations and individuals to determine on-going research not indicated in the existing literature:

American Ordnance Association

Henry C. Thayer

Association of the United States Army

N. J. Anthony

Bell Aerosystems Company

Gaylord J. Rich

Fairchild Stratos Corporation

Dr. Thomas Goldsmith

The Franklin Institute

Ezra S. Krendel

Harvard University

Dr. William H. Forbes

Institute for Defense Analyses

H. Wallace Sinaiko

Institute for Psychological Research

Dr. Paul G. Ronco

National Rifle Association

Stanford Research Institute

John J. Kimbark

U.S. Army

Brooke Army Medical Center, Fort Sam Houston, Texas
Col. Tom O. Mathews

U.S. Army Chemical Research and Development Laboratories, Maryland
Dr. F.N. Craig

U. S. Army Combat Development Experimentation Center, Fort Ord, California
Col. William J. Dennis

U.S. Army Continental Army Command, Fort Monroe, Virginia
Major O. C. Hall

U.S. Army Resources Research Office, Washington, D. C.
Mrs. Elizabeth Blaine
Mrs. Marie Leath
Miss B. Rathbone

U.S. Army Infantry School, Fort Benning, Georgia
Miss Laurie Jones
Book Department

U.S. Army Medical Research Laboratory, Fort Knox, Kentucky
Dr. George S. Harker

U.S. Army Ordnance Corps

Frankford Arsenal, Philadelphia, Pennsylvania
Alex Smith

Ordnance Liaison Group, Durham, North Carolina
Allen P. Blade

Picatinny Arsenal, Dover, New Jersey
Paul S. Strauss

Springfield Armory, Springfield, Massachusetts
H. F. Hawthorne

U.S. Army Quartermaster Field Evaluation Agency, Fort Lee, Virginia
Dr. Howard W. Hembree

U.S. Navy

Naval Medical Field Research Laboratory, Camp Le Jeune, North Carolina
Commander J. J. Martorano

Naval Training Device Center, Port Washington, New York
Dr. Kenneth F. Thomson